David Taylor Research Center
Bethesda, Maryland 20084-5000

30 July 1991

Marine Corps Programs Office

DEVELOPMENT AND TESTING OF A HYDROPNEUMATIC SUSPENSION SYSTEM ON A USMC AAV7A1

- Final Report from Cadillac Gage-Textron
- Test Report from AVTB
- List of NAVSEA Drawings Numbers and Titles
- Absorbed Power Meter Operators Manual

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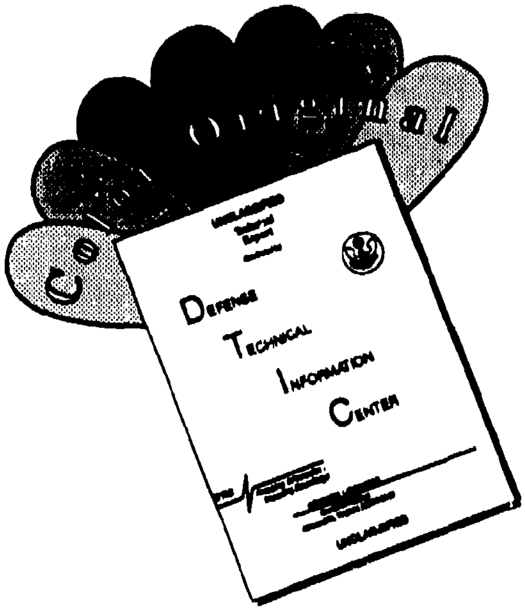

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This report discusses development, fabrication, and testing of an externally mounted, in-arm hydropneumatic suspension system on a United States Marine Corps (USMC) tracked amphibious vehicle (model AAV7A1). The suspension system was developed for a 60,000 pound vehicle and tested for performance and durability at the USMC Amphibian Vehicle Test Branch. This report contains test data and analysis resulting from this testing, in addition to contractor test results obtained. The contractor completed and documented in this report a feasibility effort to demonstrate retractability of this type suspension for future USMC amphibious vehicles. This report contains information on a digital ride quality meter fabricated by the contractor for use on this program. Testing under this program did not result in ride quality data being taken.

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FINAL REPORT
FOR AN
IN-ARM HYDROPNEUMATIC
SUSPENSION SYSTEM
FOR THE AAV7A1 VEHICLE

CONTRACT NO. N00167-88-C-0024

FOR

DAVID TAYLOR RESEARCH CENTER

Accession For

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UNCLASSIFIED ABSTRACT

The purpose of this program was the design, development, fabrication, and field test of a hydropneumatic suspension system for the AAV-7A1 Amphibian Assault Vehicle. The system consists of twelve (12) self-contained, externally-mounted in-arm suspension units (ISU) and two (2) spare units. The ISU is constructed with a hydropneumatic spring within the roadarm and a hydromechanically-controlled, friction disc damper located within the roadarm spindle.

The award of Contract #N00167-88-C-0024 in January 1988 by the Marine Corps Program Office of the David Taylor Research Center (DTRC) to Cadillac Gage Textron Inc. (CGTI) began the four-task program. After the conclusion of Phase I, the design phase, the Design Report for an In-Arm Hydropneumatic Suspension Unit, dated September 1988, was published and distributed. This report is available from the David Taylor Information Center (DTIC No. A205094). The program eventually culminated in vehicle testing at the Marine Corps Amphibian Vehicle Test Branch (AVTB), Camp Pendleton, California. The basic scope of work and field support were completed by November 1990. An added scope of this contract was the design and laboratory test of a retractable ISU. The final report for this effort is included in this document as an addendum.

TABLE OF CONTENTS

TABLE OF CONTENTS (Cont'd)

APPENDICES

LIST OF ILLUSTRATIONS

ADDENDUM Design Report - Retractable Hydropneumatic Suspension System Proof of Principle

1.0 INTRODUCTION

This final report is in response to CDRL Item No. 0004 of Contract No. N00167-88-C-0024, Task IV. Included is a review of Task I, the design of a hydropneumatic in-arm suspension system; and a summary of Task II, fabrication and laboratory test, and Task III, vehicle installation and field testing.

1.1 Background and Scope

The award of Contract No. N00167-88-C-0024 to Cadillac Gage Textron by the Marine Corps Program Office of the David Taylor Research Center occurred in January 1988. As is specified in the Statement of Work (SOW) of the contract, the suspension system consists of 12 units plus two spares, and all hardware to integrate the units into an AAV7A1 vehicle.

Task I, CDRL Item No. 0001, the design phase, encompassed the conceptual design, vehicle installation and unit layout, and component detailing of the 6,000-pound static load capacity (6K) in-arm suspension unit (ISU), shown in Figure 1-1. Vehicle load analyses, classic stress and finite element analyses, and simulated vehicle ride analyses using the VEHDYN II ride modelling program were performed during this phase.

Task II, CDRL Item No. 0002, consisted of component procurement and fabrication, unit assembly, and laboratory testing. Testing was performed on component assemblies before installation into the ISUs, as well as on the 6K unit assemblies.

During Task III, CDRL Item No. 0003, upweighting of the test vehicle, installation of the 6K suspension system, instrumentation of the system to record unit velocities and pressures, and vehicle absorbed power, and field testing were accomplished. The test vehicle was a prototype AAV7A1 chassis designated the LVTPX-12, shown in Figure 1-2. Vehicle testing was performed at Cadillac Gage's Warren, Michigan facility, testing facilities in Oxford, Michigan, the Marine Corps Amphibian Vehicle Test Branch (AVTB) at Camp Pendleton in Oceanside, California and the Marine Corps Air Ground Combat Center (AGCC) in Twenty Nine Palms, California.

1.2 Objective

The purpose of this report is to summarize the above tasks, including problems that were identified during laboratory testing, vehicle installation, and field testing, and the design changes made and proposed as a result of these identified problems. This is discussed in the following sections.

2.0 SUSPENSION DESIGN REVIEW

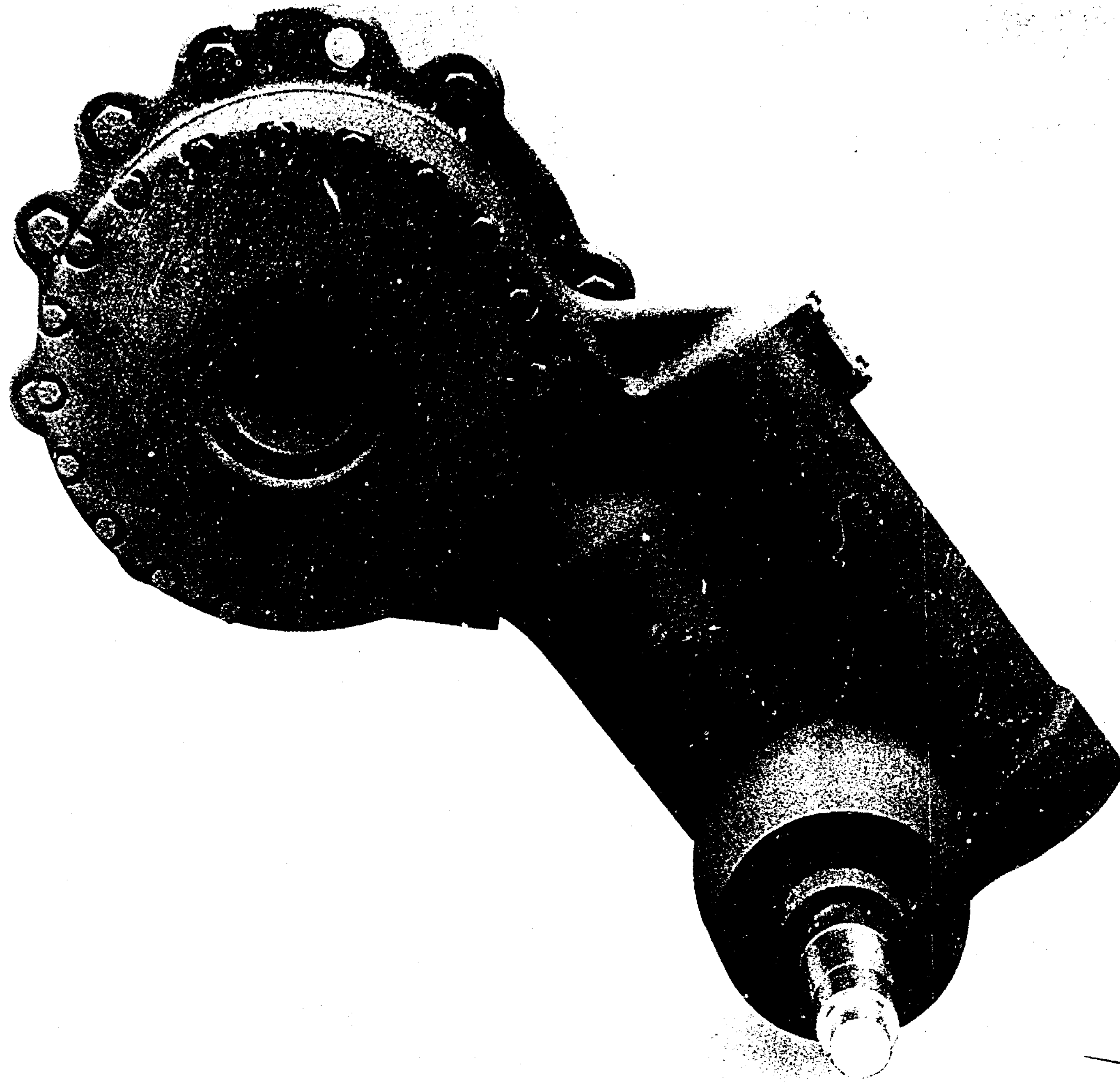

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FIGURE 1-1

FIGURE 1-2

2.1 System Requirements

The objective of the contract was the design of a hydropneumatic suspension system for the AAV7A1 assault amphibian vehicle that was lightweight, self-supporting, corrosion-resistant, improved vehicle performance, and maximized vehicle interior volume. The system specifications called for twelve units with adjustable dampers, and the capability of providing for roadwheel loading of 3.5g's and a 15% vehicle weight growth. Contract system requirements were as follows:

1. Minimum vehicle ground clearance of 16 inches.
2. Vehicle heave frequency of 1 to 1.5 Hertz.
3. System weight target of 2,250 pounds.
4. Minimum of 12 inches of jounce travel and 4 inches of rebound travel.
5. Able to operate in temperatures from -65 to 125 degrees Fahrenheit.
6. Able to withstand bearing loads of 34,235 pounds vertical, 20,000 pounds lateral, and a combination of 17,300 pounds lateral and 21,600 pounds vertical.
7. Clearance of 2.124 inches maintained between the inside edge of the track and the vehicle hull.

2.2 CGT Design Parameters

Table I, below, lists the design parameters for the CGT suspension unit and system.

Table I.
Suspension Design Parameters

Suspension System	CGT Design
Weight (lbs.)	
Unit	285.0
System	3,729.8
Pitch Frequency (Hz.)	0.882
Bounce Frequency (Hz.)	1.009

Table I. (Cont'd)
Suspension Design Parameters

Suspension System	CGT Design
Temperature Effects	1" vertical change per 60°F
Vehicle Weight Growth	15%
Durability (hrs. to rebuild)	1,000
Maintenance	100 dynamic hrs.
Corrosion Protection	Methods included in Design Report
Ballistic Protection	7.62-mm AP @ muzzle and 0° obliquity (2)
Installation	
Lateral Clearance (in.)	
Track Centerline to Hull	12.625
Track to Hull	2.125
Ground Clearance (in.)	17
Track Length on Ground (in.)	155
Suspension Unit	
Structural	
Bearing Loads (lbs.)	
Vertical	34,235
Lateral	20,000
Combined	
Vertical	21,600
Lateral	17,300
Spring System	
Road Wheel Travel (in.)	
Jounce	12.5
Rebound	5.0
Spring Rate, Max. (g's)	3.5 @ 6K, 3.0 @ 7.2K
Damper System	
Damper Rate, Max. (lbs.)	6,000

2.3 In-Arm Suspension Description

To more easily describe the In-Arm Suspension Unit (ISU), it can be separated into three basic functional elements. These are:

- ♦ Spring - The spring system provides the necessary resistive force by compressing a nitrogen charge to oppose road wheel forces input by static vehicle load and terrain disturbances over which the vehicle is traveling.

- ♦ Damper - The damper system provides the necessary forces to minimize vehicle pitch and heave and is activated in response to the velocity and position of the road wheel. The damper is comprised of a hydromechanical, wet multiple-friction disc mechanism located within the center section of the roadarm spindle.

- ♦ Structure - The ISU structure contains the damper, spring, and bearing systems and is designed to meet or exceed the load criteria as required by the vehicle application and/or the customer specification.

2.3.1 Spring System

2.3.1.1 System Description

The hydropneumatic in-arm suspension unit spring is a slider-crank mechanism, as depicted in Figure 2-1. Rotation of the roadarm in the jounce direction causes an increase in the compression of the entrapped nitrogen volume. This compression results in an increase in gas temperature and pressure as described by the nitrogen real gas equations. An increase in pressure is translated by the slider-crank linkage and results in increasing torque on the roadarm. Thus the interaction of geometry and gas compression forms the gas spring system.

Several key elements comprise the spring system. Variations of these parameters within specified design constraints result in changes to the overall gas spring performance. These elements are:

- ♦ Slider-crank geometry
- ♦ Entrapped gas/oil volume ratio
- ♦ Gas precharge pressure

These changes are manifested by the road wheel position versus force (spring) curve.

The slider-crank geometry was optimized during the design process and cannot be adjusted once hardware is fabricated. The entrapped gas/oil volume ratio and precharge pressure were adjusted during vehicle testing to improve the vehicle's ride performance.

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GAS SPRING

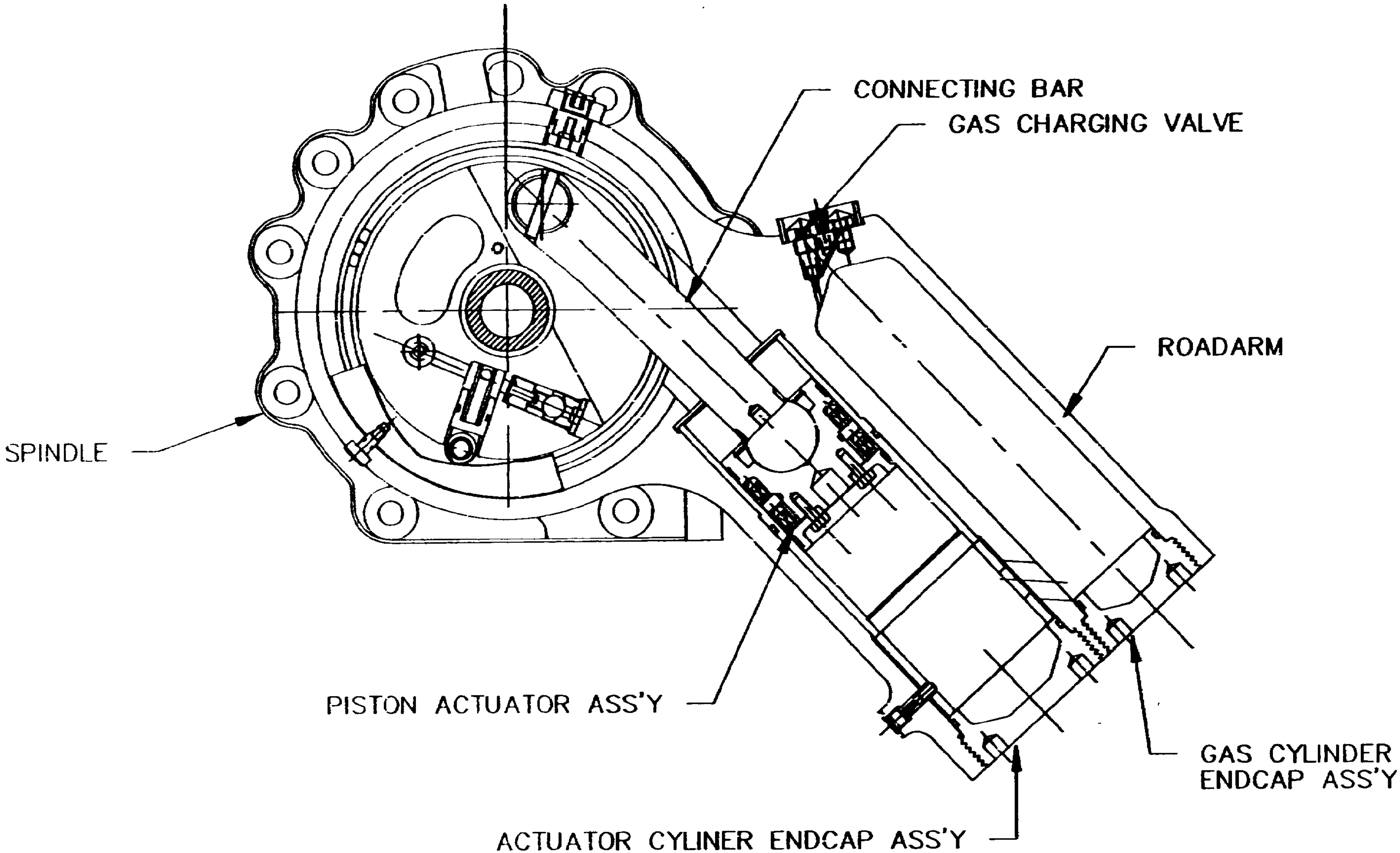


FIGURE 2-1

2.3.1.2 System Spring Rate

The spring system produces a spring rate which varies as a function of wheel position. The rate at the static wheel position is relatively low, providing improved ride quality. However, as the wheel approaches the jounce position, the spring rate increases dramatically, to prevent "bottoming out" on rugged terrain. The characteristics of this variable rate spring are shown in the adiabatic curve of Figure 2-2. Due to friction inherent in the system, the spring load varies through the range illustrated as the unit goes from the static position to jounce and into rebound.

2.3.1.3 Spring Sealing System

A piston seal was sized for the ISU design based on the velocity of the unit and the force seen by the spring system.

This seal consists of a wedge loaded sealing surface acted on by an expansion ring with multiple coil springs to provide an initial preload on the sealing surface. The wedge seal is fabricated from polyimide, which is a very high modulus, high strength plastic. The wedge seal material resists extrusion under high pressure while conforming to irregularities in the mating steel surface, thus forming an effective high pressure seal.

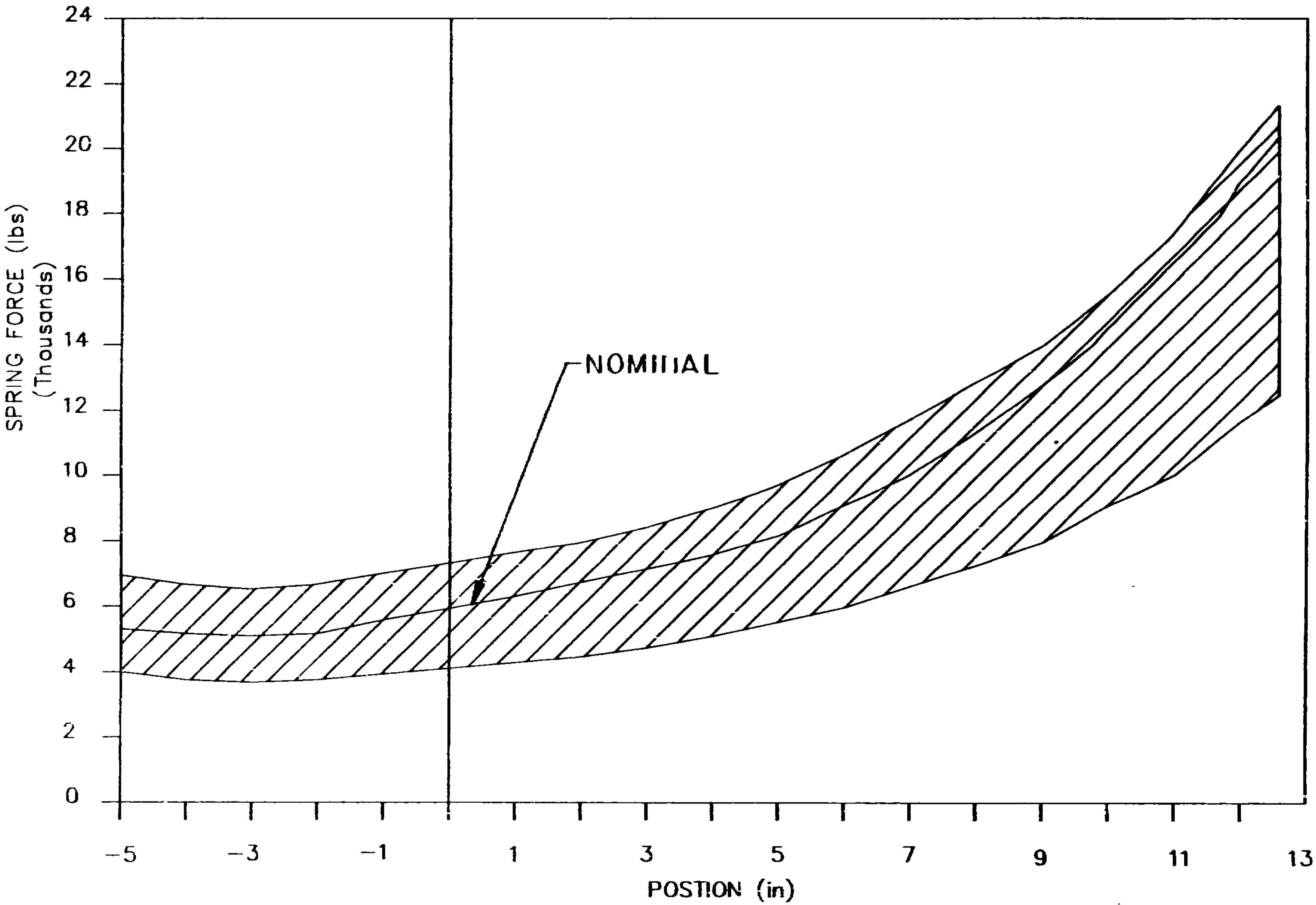
Two Cadillac Gage designed spring loaded seals are used in series on the piston. This configuration forms a buffer zone between the two seals; the first seal is exposed to the full pressure variation while the second is exposed to an almost constant static pressure of 3,100 psig. In addition, the first seal acts as a check valve by venting any increase in buffer zone pressure back to the oil chamber when the spring returns to static pressure conditions. This provides minimum leakage and wear of the second seal, and hence, improves gas spring system reliability/durability.

2.3.2 Damper System

2.3.2.1 System Description

The components of the damper mechanism consist of a hydromechanical open loop control system and a wet, multiple-friction disc pack installed within the roadarm spindle and activated by the rotating roadarm. The cross-section of the damper is shown in Figure 2-3. The damper system functions when the roadarm assembly rotates, which forces a cam mounted to the roadarm to drive a piston pump, thereby developing pressure. This pressure, which by virtue of cam cut and relief valve is a function of wheel velocity and position, acts on the damper piston, which then develops an axial clamping force on the friction disc pack. The disc pack's function is to

6K ISU SPRING LOADS
SPRING LOAD VS. POSITION



FIGIIF 2-2

DAMPER SECTION

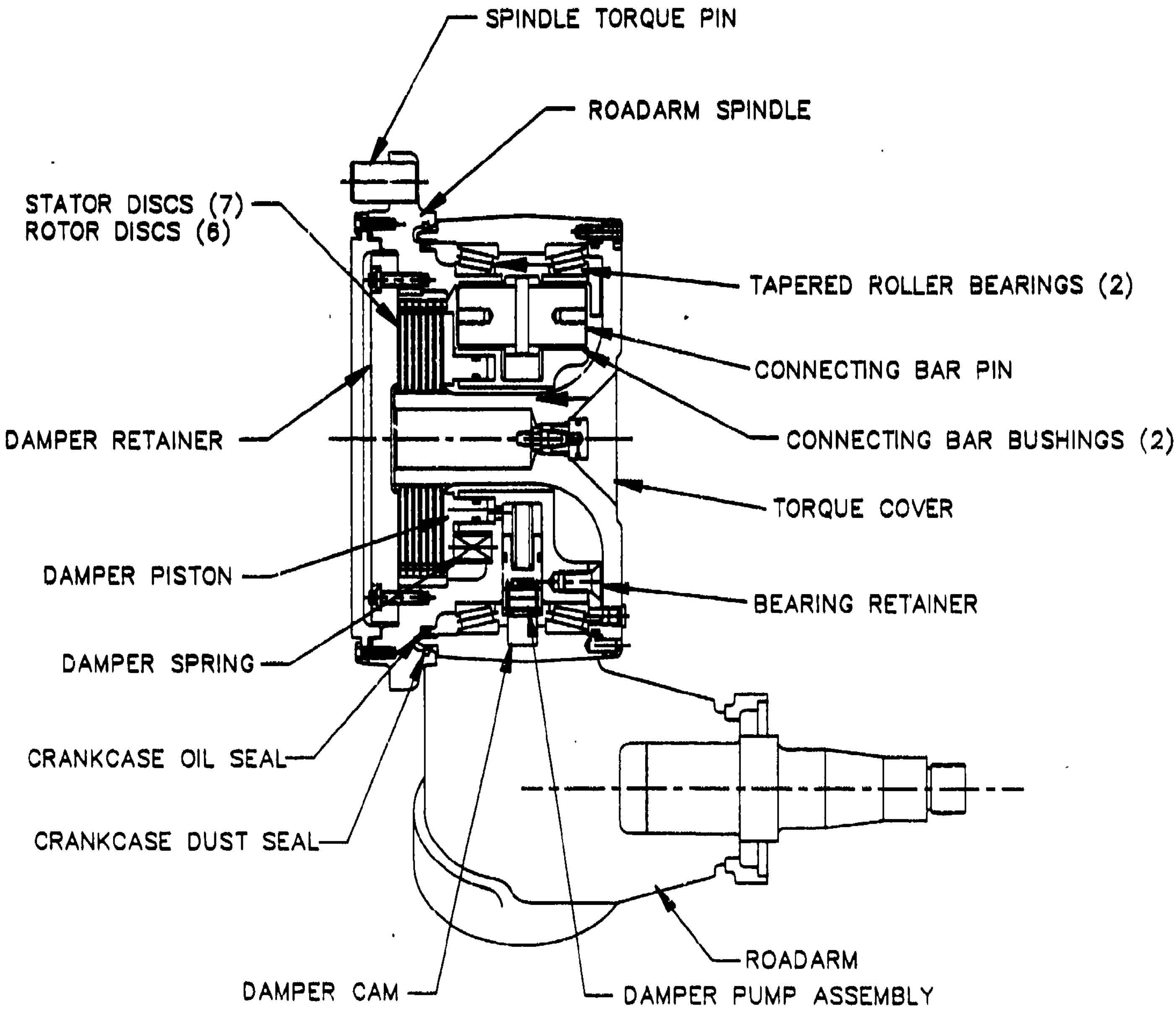


FIGURE 2-3

provide a constant slip torque proportional to the applied clamp load, which when rigidly connected to the roadarm, translates into a wheel damping force opposing roadarm rotation. Maximum pressure and pressure rise rate are controlled by the relief valve and internal orifice. When the roadarm returns, the spring loaded pump and check valve resupply the hydraulic fluid in the control system. The damper springs provide a nominal load on the disc pack for low speed damping. The damper subcomponents are shown schematically in Figure 2-4.

2.3.3 Structure

The final functional element of the ISU is the structural element. Stress information gained from previous ISU design experience contributed to the design of the major components of this medium ISU. Both classical and finite element techniques were used to assure the structural integrity of the unit. See CGT Design Report for ISU Model 6KA1-AAV-01-03, dated September 1988 for these results.

2.3.3.1 Load Criteria

All suspension unit components shall have adequate structural integrity to withstand the various load conditions defined below without permanent deformation, long-term durability failures, or extreme rupture, as applicable.

2.3.3.1.1 Maximum Load Conditions

Load Condition	Wheel Load, lbs (g) Vertical	Lateral
Static	7,200 (1 g)	0
Jounce	21,600 (3 g)	0
Combined	21,600	±17,300
Max. Lateral		±20,000
Max. Vertical	34,245 (proof)	

2.3.3.2 Stress Analysis

A classical stress analysis was performed for all major components that might be affected by the forces exerted on the ISU assembly during its operation, including a determination of minimum and maximum stresses and fatigue characteristics where deemed necessary. A finite element analysis was completed for

DAMPER SYSTEM MODEL

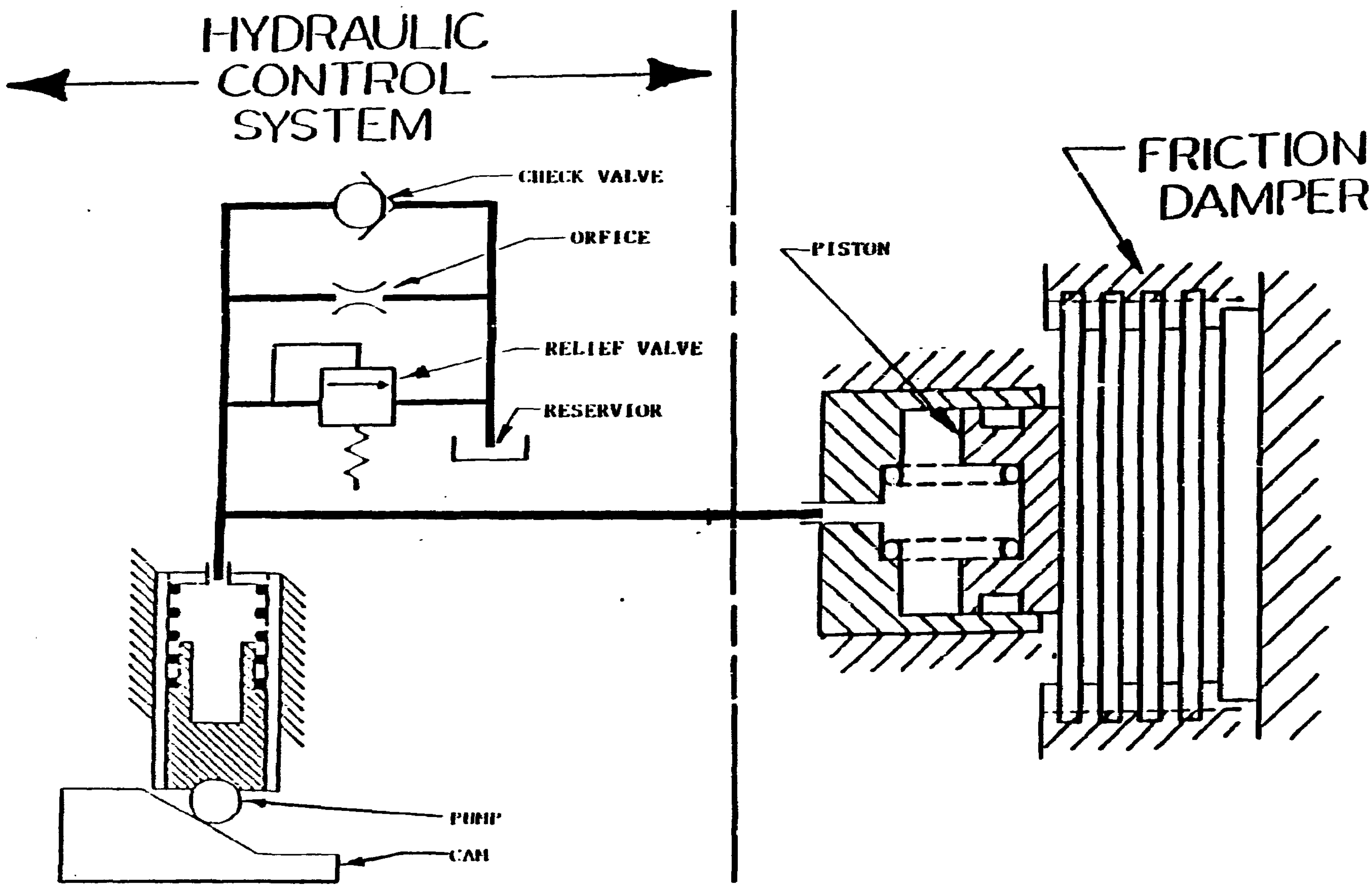


FIGURE 2-4

the initial roadarm design, roadarm spindle, torque cover, and end cap. See the CGT Design Report for ISU Model 6KA1-AAV-01-03 for the details of this analysis.

2.4 Environmental Effects

This hydropneumatic suspension design has been developed to minimize the environmental impact on the integrity of the ISU system.

2.4.1 Thermal

A gas spring's operational characteristics are affected by both ambient temperatures while not in operation and by an increase in the system temperature from the damper during dynamic operation of the vehicle.

2.4.1.1 Ambient

In accordance with the laws of thermodynamics, temperature has a significant impact on the nitrogen gas pressure in the spring system. The gas pressure will increase or decrease as temperature increases or decreases, which will vary the force opposing the road wheel load. The result will be a variation in the vehicle height due to changes in temperature. Optimizing the spring system geometry will minimize this effect, but not eliminate it. The results of a temperature sensitivity analysis performed for this design shows that a ±60°F change will alter the vehicle height by ±1 inch.

2.4.1.2 Operational

Dynamic operation of the vehicle also impacts the nitrogen gas spring due to the temperature increases developed in the damper section. Experience with testing performed on both the M1A1 and LVPTX-12 vehicles has shown these effects to be minimal. During testing at AVTB, ISU crankcase and body temperatures of only 160° F were recorded on an 80° F day after several hours of cross country operation. Temperature measurements of 170° F were recorded during testing at AGCC on a 120° F day after several hours. This can be compared to temperatures of 400° F to 500° F measured on the standard M1A1 rotary shocks after vehicle operation. Due to the large size of the ISU's frictional damper and efficient heat transfer into the vehicle hull, temperature effects due to dynamic operation of the unit have been minimized.

2.4.2 Corrosion

All necessary precautions will be followed to insure the protection of the ISU from corrosion. These precautions include the appropriate material selection, surface treatment, corrosion protection, priming, and painting as defined in standards:

MIL-HDBK-132A	Protective Finishes for Metal and Wood Surfaces
MIL-STD-171D	Finishing of Metal and Wood Surfaces
MIL-STD-193K	Painting Procedures and Marking for Vehicles

Further, to minimize galvanic corrosion, components of the ISU exposed to saltwater were finished based on the guidance provided in Table I of MIL-STD-171 to ensure the compatibility of mating components made of dissimilar metals.

2.5 Ballistic Protection

To establish the armor thickness required for protection from a 7.62-mm armor-piercing projectile at 0° obliquity, a computer program was used that was written by Cadillac Gage based on published information from John Hopkins University and other sources, including the Army Materials and Mechanics Research Center. It was determined that a minimum thickness of 0.5-inch 4340 steel alloy armor was needed.

2.6 Maintenance

The ISU is designed to be easy to maintain by virtue of positioning the damper charge valve, gas spring charge valve, and crankcase oil filler plugs in locations that are accessible with the road wheel installed on the unit.

The crankcase acts as a damper oil reservoir. The damper fluid need not be changed over the life of the ISU, and will rarely, if ever, require additional oil except in the case of unit damage. The crankcase pressure can be checked using a tire pressure gage on the damper charge valve located on the top of the crankcase. The relief valve, incorporated as a precaution against over-pressure in the crankcase, is self-cleaning and should not require servicing.

The gas spring is easily maintained and is designed for simple service at a six-month interval. Inspection or adjustment of the spring pre-charge is easily accomplished through the charging valve located on the top of the roadarm near the end cap. Any need to adjust the gas spring may be determined by changes in the vehicle height and attitude. The Operation and Maintenance Manual for a Hydropneumatic Suspension System, found in Appendix A, details the maintenance procedures.

2.6.1 Charging Cart

In order to perform any maintenance required on the in-arm units, a charging cart consisting of two nitrogen-filled tanks, a pressure booster and regulator, an oil tank, various hoses for oil and nitrogen discharge, and a hydraulically-operated lifting arm for vehicle removal and installation of the ISU's was built and included as part of the HSS system. This cart was not optimized for Marine Corps use with the test vehicle; it was, however, built using commercially-available components and thus could be easily redesigned per customer specifications. A photograph of the charging cart is shown in Figure 2-5. Operational procedures are found in the Operation and Maintenance Manual in Appendix A.

2.7 Unit and System Weight

The actual weight of an individual, fluid-filled ISU, including the Bradley Fighting Vehicle (BFV) hub and spindle, is 285.0 pounds. The weight of the 6K suspension system, which includes the support rollers, mounting plates, jounce stops, torsion bar hole plugs, and the twelve (12) ISUs, is 3,729.8 pounds. A weight-by-component list can be found in the CGT Design Report for ISU Model 6KA1-AAV-01-03.

3.0 FABRICATION AND LABORATORY TEST

3.1 Hardware Procurement and Assembly

3.1.1 Inspection

A source inspection was performed for all hardware with critical dimensions. During the source inspection, material and material process specifications were also reviewed.

3.1.2 Pre-assembly Preparation

The hardware was prepared for assembly per an assembly procedure developed by Cadillac Gage Textron.

The first and most crucial step in the pre-assembly was the deburring and cleaning step. The deburring process involved the removal of all sharp edges left after fabrication throughout the parts, concentrating on the damper and spring hydraulic sections. Following this, the hardware was mechanically cleaned to remove any grease or oil used during shipment for rust prevention, and any dirt or rust that may have accumulated during storage. The components were chemically cleaned first in a wash tank filled with a water-based soap solution, then with alcohol, and finally dried with pressurized air.

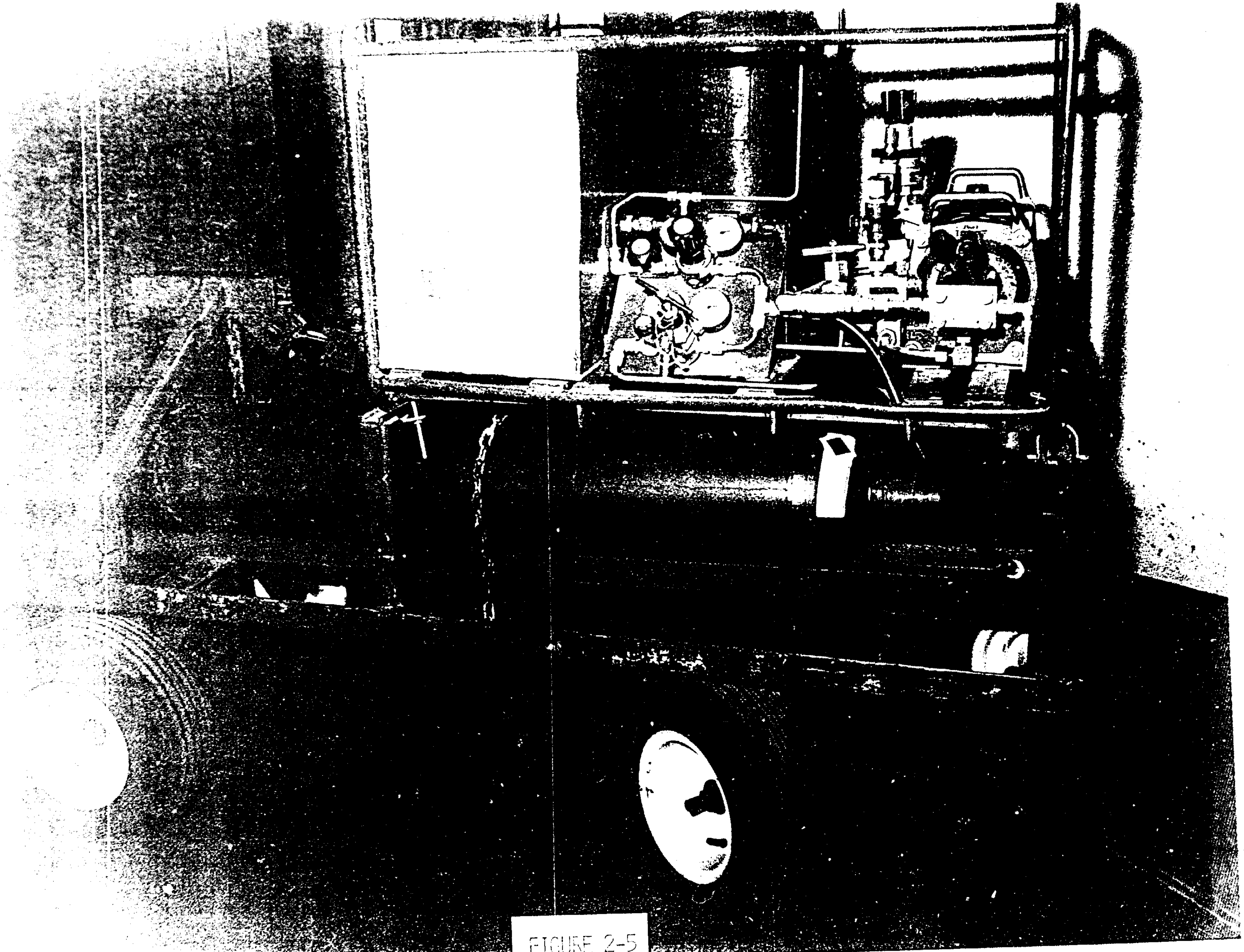


FIGURE 2-5

3.1.3 Unit Assembly

Final assembly was performed in the Clean Room, which maintains a controlled atmosphere, regulating humidity and keeping airborne dust particles to a minimum. The unit assembly was performed using several specially designed and fabricated tools and fixtures. A list and description of these is provided in Appendix B.

In the assembly process, several special tests and procedures were developed to validate the assembly up to that point and facilitate unit acceptance testing. The first of these special procedures was the filling of the damper hydraulic cavity to eliminate entrapped air which would lessen the system response. Upon completion of the damper section assembly, the control system was then pressure tested to validate the seals and identify potential leaks prior to further assembly. Another in-process check was the evaluation of roadarm rotational torque resistance after assembly onto the spindle to check the crankcase seal installation. Excessively high resistance might indicate a pinched seal, which could be easily repaired at that time. A procedure was also developed to adjust and properly preload the main bearings to obtain a consistent setting and performance.

3.2 Laboratory Test

3.2.1 Acceptance Test Procedure

Each of the fourteen ISUs was acceptance tested per the preliminary Acceptance Test Procedure which appears in Appendix C. This testing, done on a test stand that consists of a hydraulic actuator controlled through a servovalve and electronic control box, consisted of proof and functional tests. A photograph of the test cell is shown in Figure 3-1. In addition, each unit was endurance tested for a total of ten (10) hours, which included the four hour high pressure seal break-in period.

For proof testing, the units were filled with 2,400 cubic centimeters (cc) of oil, and were pressurized to 18,000 pounds per square inch (psi) for a total of five (5) minutes. The units were then drained of 600 cc of oil for a total spring oil volume of 1,800 cc. For operational testing, the units were charged with nitrogen to 3,100 psi, and the crankcases were charged to 50 psi.

A spring curve representative of the 6K units appears in Figure 3-2. Typical spring and damper curves plotted during unit cycling appear in Appendix D.

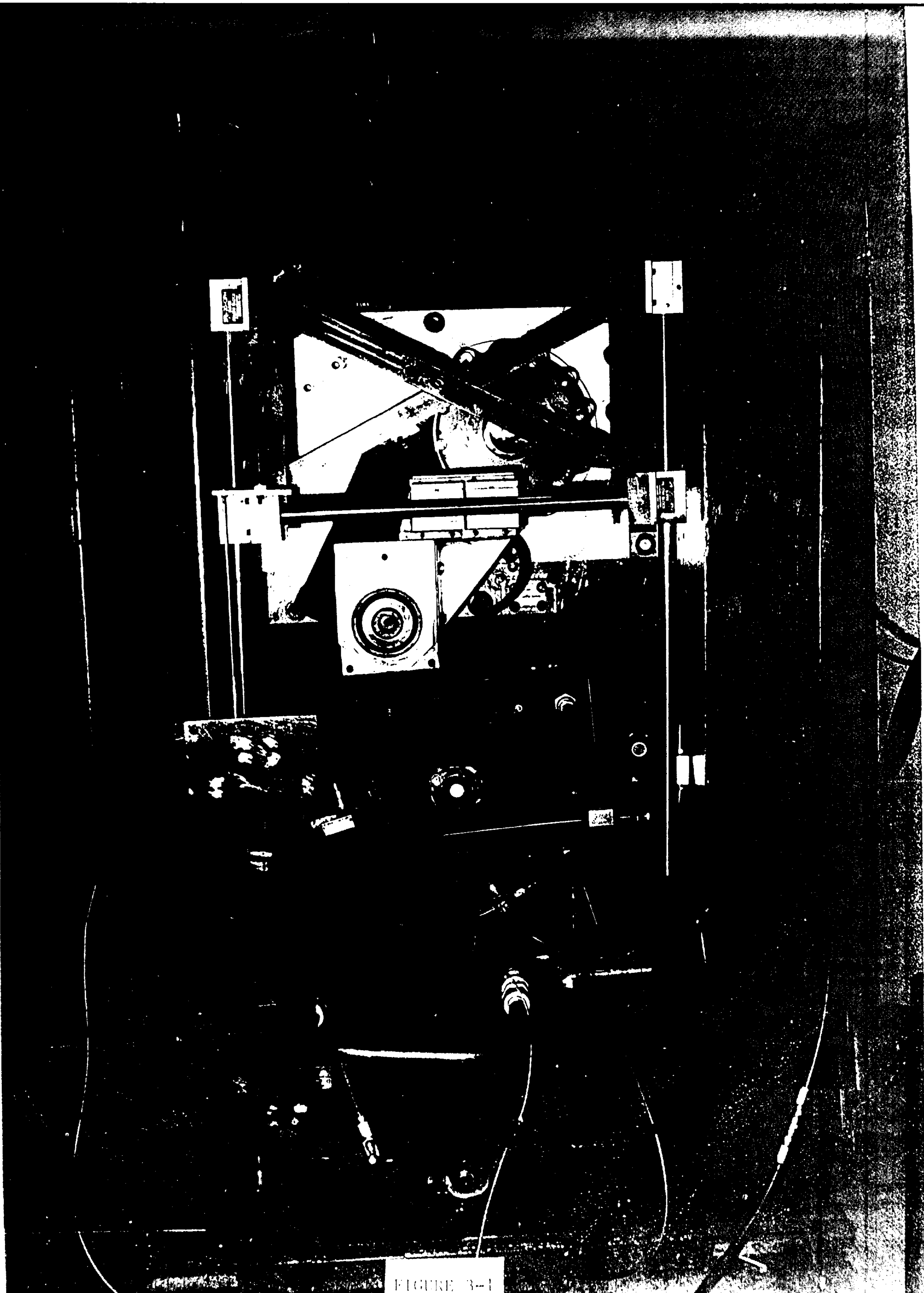


FIGURE 3-1

6K SN11 SPRING PRESSURE

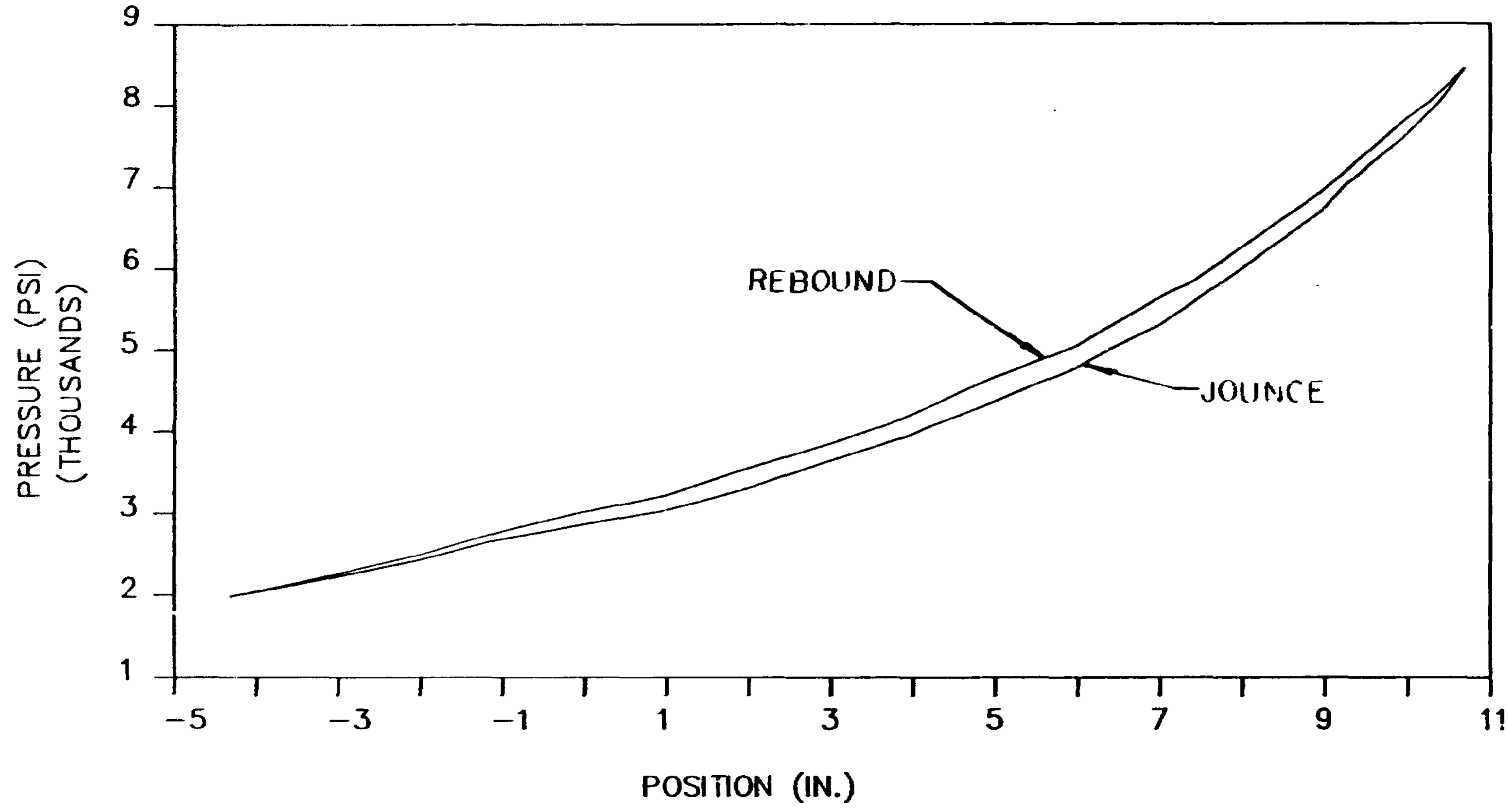


FIGURE 3–2

3.2.2 Durability Testing

In addition to the above testing, one unit, S/N 16, underwent durability testing on a laboratory test stand for a total of 310 hours, or an equivalent of 6,000 vehicle miles.

3.2.2.1 M1 Rotary Shock Qualification Tape

For durability testing, the M1 Rotary Shock Qualification Tape is utilized. This magnetic tape was developed by recording number one road wheel displacement with respect to the M1 hull versus time during cross-country vehicle operation at the Chrysler (Chelsea) Proving Grounds. This motion was then converted to proportional electrical signals and recorded on a real-time basis onto the magnetic tape. The magnetic tape itself was played into the electronic control box which drives the hydraulic servo actuator on the test stand. Thus, the actuator drives the ISU in response to electrical signals from the tape, closely simulating actual bump course load/stroke conditions. The 44-minute tape is automatically replayed repeatedly for the duration of the durability test.

3.2.3 Test Results

Each ISU successfully completed the acceptance testing performed. During the course of the testing, the anomalies described below were identified and resolved.

3.2.3.1 Connecting Bar Pin Shear

Proof testing of the second and subsequent units resulted in the occurrence of sheared connecting bar pins in the spring section of the units. Because the failure was occurring through the center of the pin, where the highest loading was taking place, it was determined that this problem was the result of the inadequacy of the original material, 52100 steel alloy, to withstand the stresses resulting from proof loading.

The problem was resolved by changing the material of the pins to an alloy tool steel, AISI S7, over the steel alloy 52100 originally used. For comparison, the yield strength and percent elongation for the 52100 alloy is 240,000 psi and 3 percent respectively, while for the AISI S7 tool steel, these values are 210,000 psi and 10 percent. The yield strength of the tool steel is equivalent, with a much higher elongation. This combination makes the S7 steel much tougher, and with the change of materials, no further problems were seen with the pins.

3.2.3.2 Damper Retainer Bending

During the durability testing of the S/N 16 unit, it was discovered that the bolts in the damper retainer were shearing at the bolt heads. It was determined that the bolts were being fatigued by excessive bending of the cover. The other units were cycled on the test stand and the same problem began occurring.

New damper retainers were fabricated with a .25-inch increase in thickness over the original design and were installed on the units. No further problems were seen.

3.2.3.3 Connecting Bar Bearing and Pump Cam Wear

Approximately half-way through the 310-hour durability test, the S/N 16 unit was disassembled for inspection of critical components. Wear areas were found on the inner surface of the fabric-lined connecting bar bearings, which led to the conclusion that the bearings were unable to withstand the loads being imposed on them. Also found were wear indications on the pump cams in the form of brinnelling and cracking of the cam faces. It was determined that the cam material, especially the surface, was of an insufficient strength and hardness to endure the loads from the pump.

Comparison endurance tests were performed on two alternative fabric-lined bearings. The bearings were cycled for more than 110 hours (200,000+ cycles) each in a test fixture designed to replicate the loading seen during ISU operation. Inner diameter measurements were recorded before the test, and then at 50,000-cycle intervals. A new bearing was chosen based which showed the least amount of wear within the specified limit.

New pump cams were fabricated using AISI A2 tool steel hardened to 58/63 Rockwell (Rc). This material has a yield strength of 210,000 psi at this hardness. In comparison, the original material, SAE 4140 steel alloy hardened to 30/34 Rc, has a yield strength of 130,000 psi.

All of the ISU's were disassembled and were reassembled using the new cams and connecting bar bearings. The system was then reinstalled on the test vehicle.

Unit S/N 16 was again disassembled at the completion of the 310 hours, and the components were visually inspected. No other problems were noted.

4.0 VEHICLE INSTALLATION AND FIELD TESTING

4.1 Vehicle Upweighting

The weight and center of gravity (CG) of the vehicle with the original torsion bar suspension were calculated in the following manner: the vehicle was driven over two I-beams for stabilization, then each end of the I-beams were lifted with a hydraulic jack and one of four 20,000-lb. load cells were placed under each end of the beams. A weight measurement was taken at each load cell; these measurements were, in pounds, 10,584, 10398, 9,162, and 10,636.

The summation of these weights, minus the weight of the beams at 1,275 pounds each, is 38,230 pounds, which is the total unloaded vehicle weight. An illustration of the beam/load cell set-up is shown in Figure 4-1.

Longitudinal measurements from the final drive to the load cells were used to calculate the CG of the vehicle, which was found to be 188.4 inches. The method used to determine the CG is shown in Appendix E.

Upweighting of the vehicle was done to bring the vehicle closer to the actual operating weight for installation and tuning of the hydropneumatic suspension system. This was accomplished by adding five (5) steel ballast plates to the interior of the vehicle, placed up against the vehicle bulkhead (as far forward as possible). The weight of the plates equalled 10,090 pounds, for a final vehicle weight of 48,320 pounds. The new CG was measured at 196.5 inches from the final drive.

The statement of work for the addition of the steel ballast plates within the vehicle can be found in Appendix F.

4.2 Vehicle Installation

The torsion bar suspension was removed from the test vehicle and weighed for reference. The original suspension mounting holes were plugged and welded in place. Aluminum I-beams were welded in place in the water jet tunnels to act as jounce stops for the aft suspension units. The vehicle was then shipped to a machine shop for machining of the mounting surfaces and bolt patterns in preparation for installation of the ISUs. Skid plates were added above the station 3 ISU on each side of the vehicle to prevent interference between the track and the units during high track sag. The units were installed on the vehicle with the aid of a charging cart specially built for use during the planned vehicle testing, and were charged to the pressures of Table I below. A modified hub cap arrangement for the track support rollers was designed and installed to avoid interference between the hub caps and track guides.

Table II.
Unit Pressures

	Station 1 & 2	Station 3-6
Spring, psi	3,100	1,500
Crankcase, psi	50	50

CADILLAC GAGE

BEAM/LOADCELL SET-UP

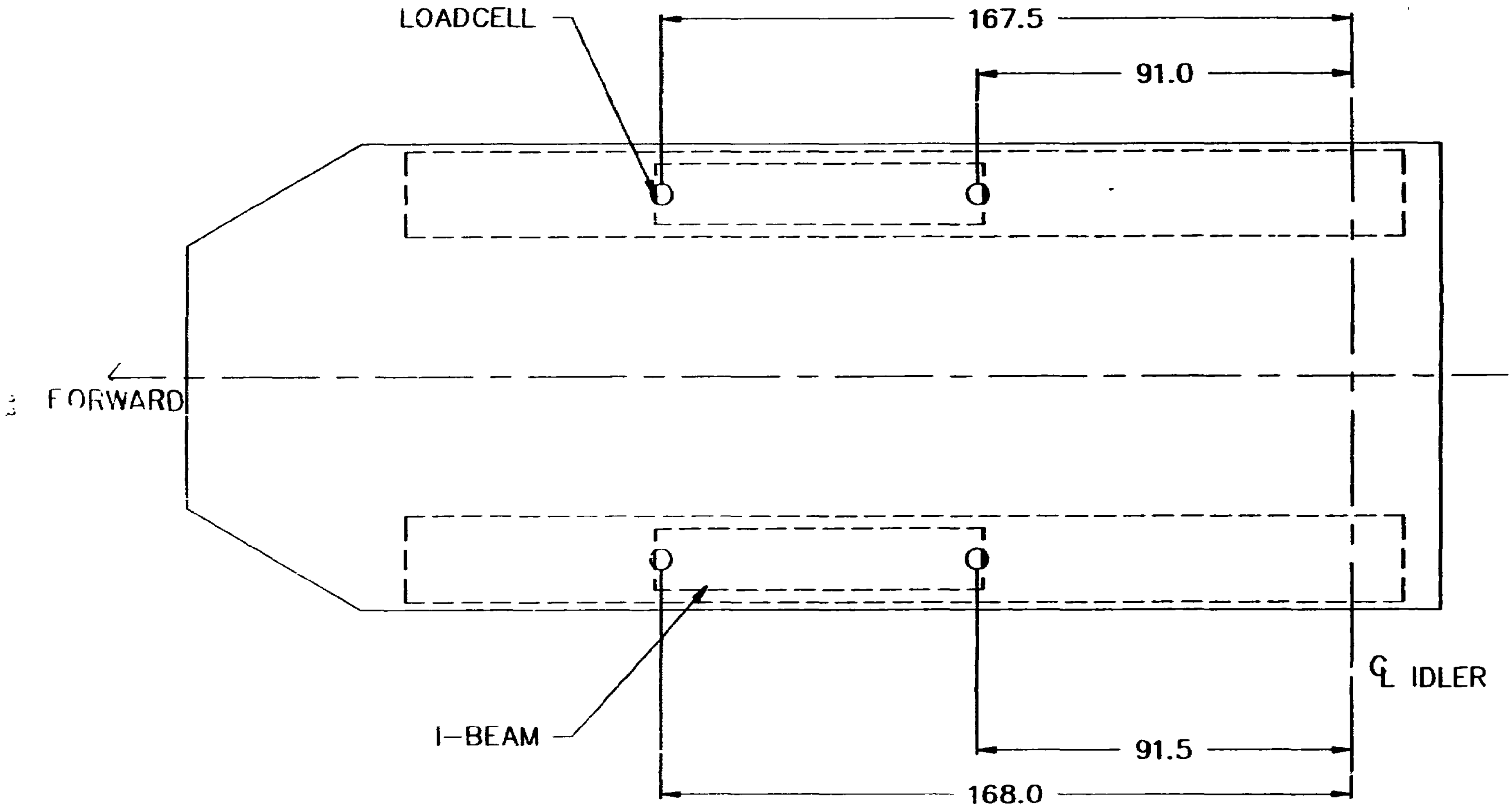


FIGURE 4-1

4.3 Field Testing

4.3.1 Vehicle Instrumentation

To evaluate the ride performance of the vehicle with the standard torsion bar suspension system and with the hydropneumatic system, the vehicle was instrumented prior to testing. A rate-integrating gyroscope was placed in the vehicle to measure vehicle pitch, an accelerometer was placed on the driver's seat to determine the amount of vertical acceleration seen by the driver, and another accelerometer was placed on the ballast plates to measure hull motion at the CG. For testing of the vehicle with the hydropneumatic suspension system, sensors were also added to station 2 and 3 ISUs to measure damper pressure, roadarm position, and crankcase oil temperature.

4.3.1.1 Ride Meter

CGT constructed two ride meters intended to aid in evaluating vehicle ride quality. The design philosophy was originally developed by the U.S. Army Tank-Automotive Command (TACOM) several years ago; the CGT ride meters used up-to-date circuitry and currently available components. The meters were to be considered part of the vehicle instrumentation.

The function of the instrument is to accept an input signal from an accelerometer mounted in the test vehicle, usually at the driver's seat. The signal is first amplified, then processed by frequency-dependent shaping filters to provide information that is weighted according to human body sensitivity. This information is put through a computation circuit network and the resulting output fed to a digital volt meter along with the output of a timing circuit. A selector switch at the meter allows the direct measurement of peak acceleration, time duration of the run, and a value which is the product of absorbed power and elapsed time during the run. A manual calculation utilizing the latter two values provides the average absorbed power experienced for the test run. An operational specification for the meter appears in Appendix G.

4.3.2 Vehicle Tuning and Preliminary Test

In order to tune the newly-installed hydropneumatic suspension system, test the instrumentation for proper response, and gather preliminary performance data on the system, the vehicle was driven through bump course runs of eight (8), ten (10), and twelve (12) inch bumps at speeds of 2.5, 5, 7.5, 10, 12.5, and 15 miles per hour (mph), and through a flat course at 18 and 22 mph at CGT's Warren facility. A videotape of the runs was made and sent to DTRC.

4.3.2.1 Preliminary Test Results

In the course of the preliminary vehicle performance testing, several problems were identified and resolved. These are as follows:

1. Rebound Stop Blocks

   Problem: Roadarm and spindle mounted blocks being sheared off during vehicle operation.

   Solution: Pin blocks to mating structures. See Figure 4-2.

2. Crankcase Relief Valves

   Problem: Relief valve being damaged during vehicle operation.

   Solution: Design and install new relief valve adapter to protect valve. See Figure 4-3.

3. High Pressure Seals

   Problem: Pre-formed seals allowing leakage of nitrogen from the spring cavity to the crankcase. To increase manufacturing efficiency, the seals were pre-formed using a die rather than machined from polyimide bar stock, which was the previous procedure. It was discovered that this pre-forming method decreased the density of the seal.

   Solution: Replace lower density pre-formed seals with higher density machined seals.

After rebuild of the units to incorporate the above modifications, they were installed back onto the vehicle and testing was continued at CGT and then at a test facility in Oxford, Michigan. Problems with the vehicle power plant halted further testing at this facility.

4.3.2.2 Preliminary Vehicle Ride Data

Data was collected for driver's seat acceleration and vehicle pitch versus time on course runs made with torsion bar suspension and with the hydropneumatic suspension. Other parameters such as acceleration at the vehicle CG and suspension position were not accurately recorded during the course of the test runs due to equipment trouble.

CADILLAC GAGE

REBOUND STOP BLOCKS

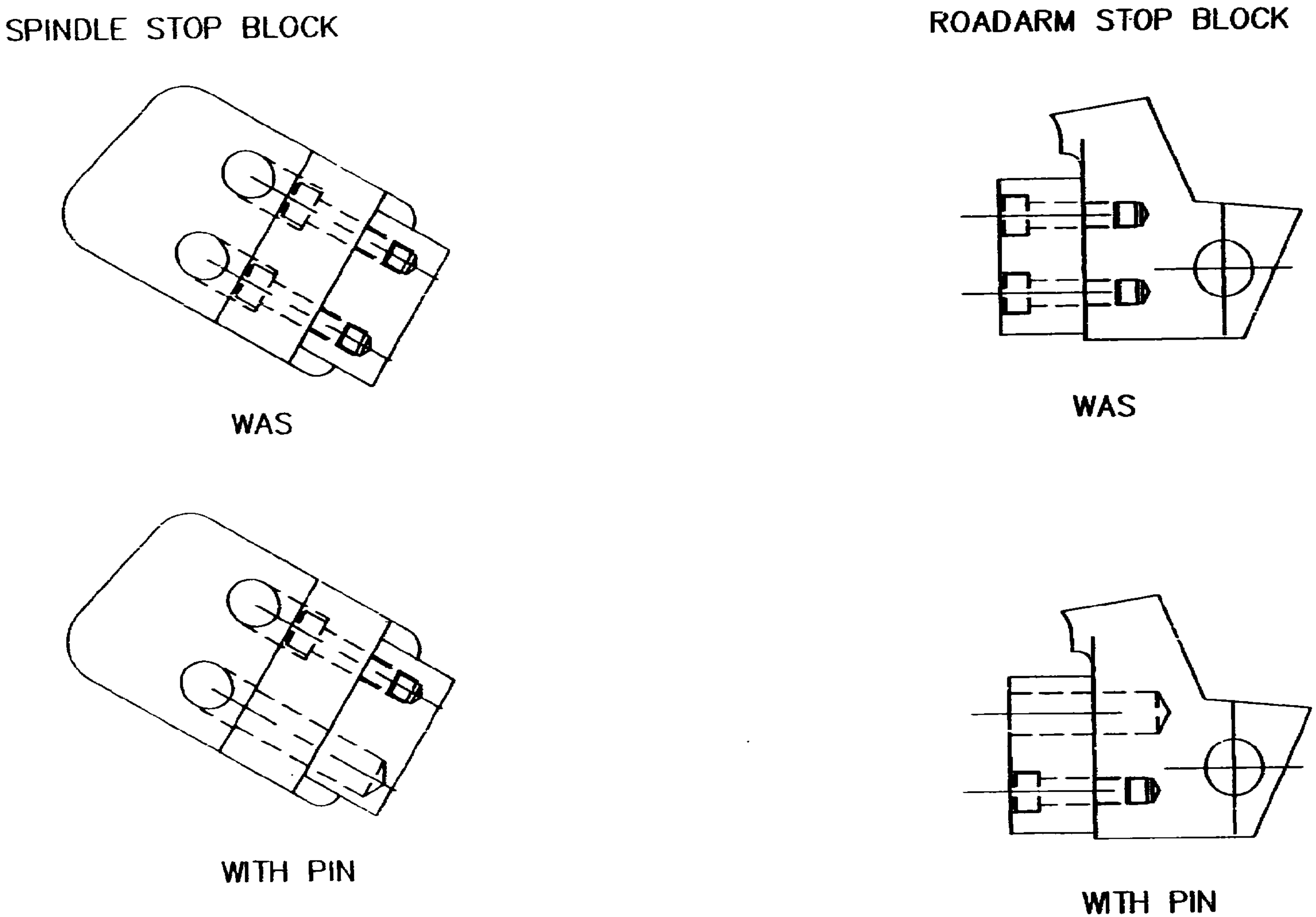


FIGURE 4-2

CADILLAC GAGE

RELIEF VALVE ADAPTER

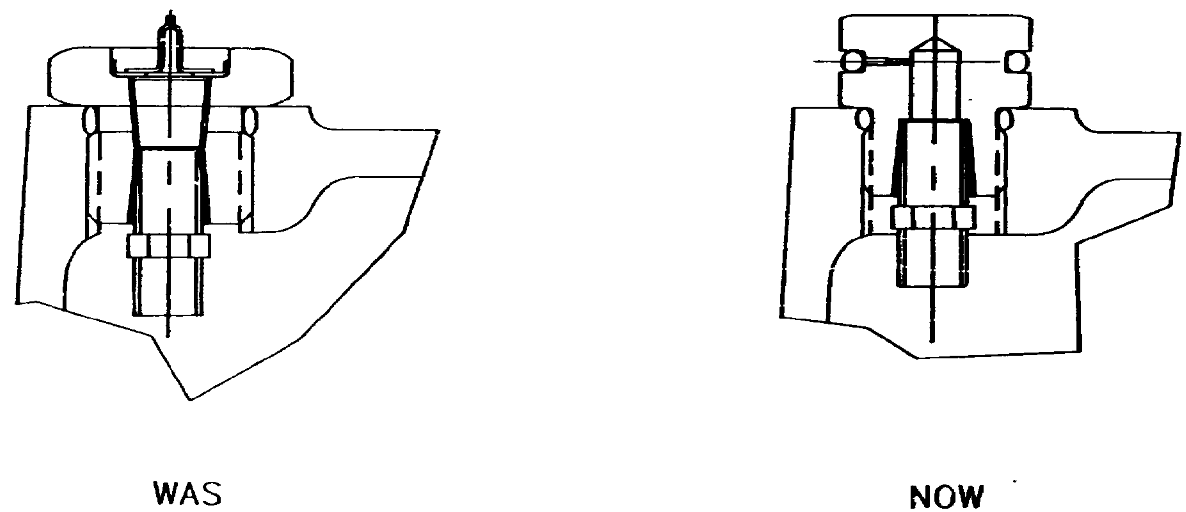


FIGURE 4-3

Figures 4-4 and 4-5 show pitch and acceleration data plotted for runs made with t-bar and hydropneumatic suspensions. Both runs were made at fifteen (15) miles per hour (mph) over a discrete obstacle course of bumps at eight, ten, and twelve inches, respectively. In comparing the two sets of data, it can be seen that the degree of vehicle pitch is less with the HSS than with the t-bar system, especially negative pitch (vehicle going nose-down upon landing after a bump). There is a significant amount of difference between the data curves when comparing the data for the twelve-inch bump, with the vehicle reaching a positive pitch of ten (10) degrees and a negative pitch of eight (8) degrees with the t-bar system, in comparison with 5 degrees both positive and negative with the ISU system. This difference is due to the fact that the ISU will attempt to swallow bumps shorter than its wheel travel (the eight and ten inch bumps), and will try to lift the vehicle over bumps of equal or greater height than its wheel travel (the twelve inch bump).

Also plotted was the acceleration, in g's, seen at the driver's seat. The vehicle experienced peak g's of two (2) at the second bump and more than four (4) at the third bump of the course with the t-bar system, while the peak g's recorded for the ISU system over these bumps were 1.5.

Figure 4-6 is a summary plot of the peak g's for both the t-bar and the ISU systems at vehicle speeds of 5 to 20 mph. It can be seen that the ISU system provides a marked improvement over the t-bar system. Figure 4-7 is a plot of average absorbed power versus speed for the t-bar and ISU systems. This comparison also shows a significant improvement in vehicle ride with the hydropneumatic suspension system. This improvement is particularly enhanced at higher vehicle speeds.

4.3.3 Vehicle Field Testing

4.3.3.1 Advanced Demonstration Test Plan

The Test Plan for a Hydropneumatic Suspension System Mounted on an Assault Amphibian Vehicle, prepared by the David Taylor Research Center (DTRC), outlines the plan that the test vehicle was to undergo. This plan, which can be found in Appendix H, calls for an accumulation of 6,000 miles of operation through a normal vehicle profile (20% water operation, 80% land operation), which is equivalent to one life cycle. The test plan also attempted to establish the performance capabilities of the hydropneumatic system. According to the plan, the following types of tests were conducted at the Amphibian Vehicle Test Branch (AVTB), Camp Pendleton, California. Hot weather testing was conducted at Twenty-Nine Palms, California.

- Ride Quality
- Cross Country Test Course

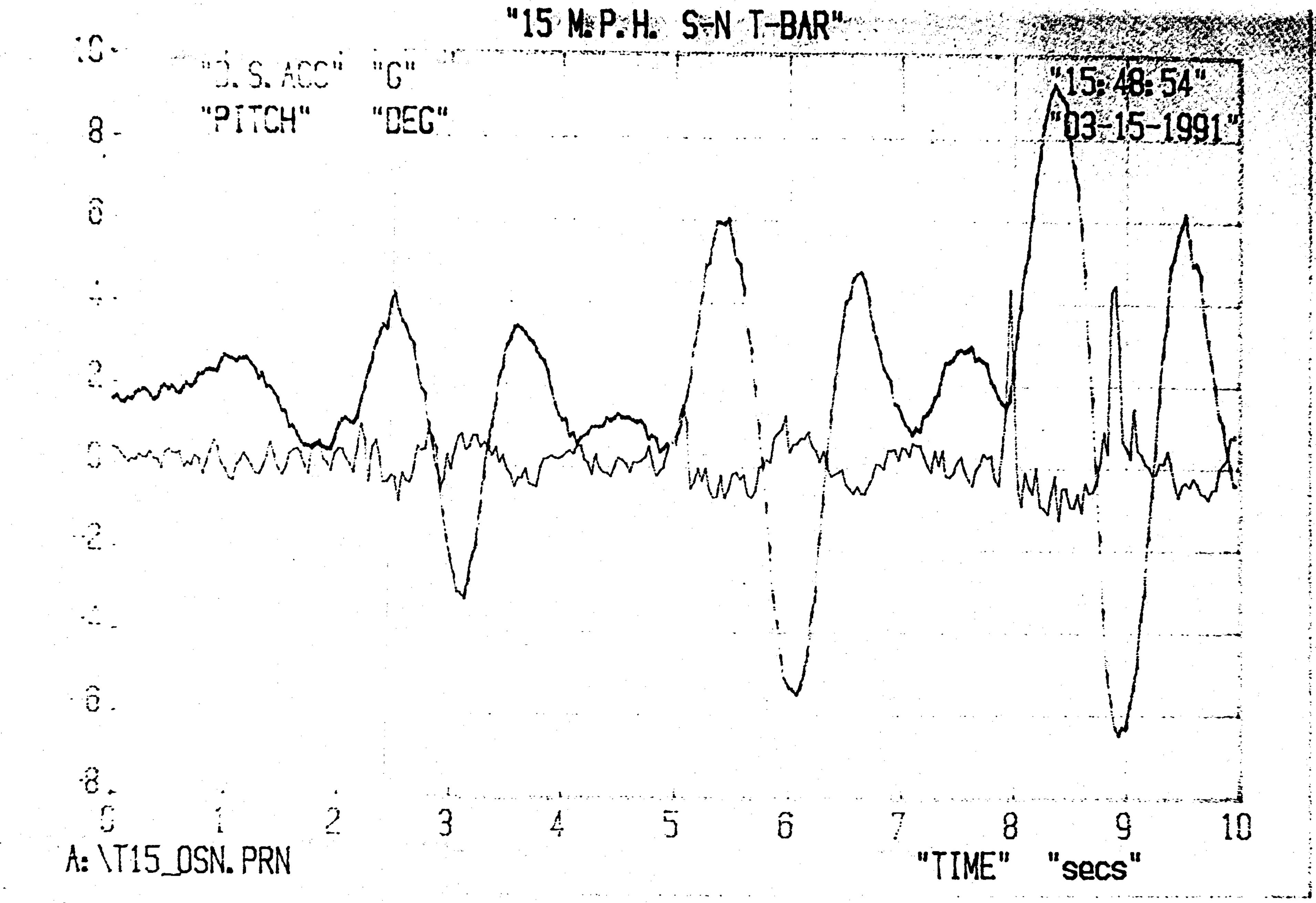

"15 M.P.H. S-N T-BAR"
"D.S.ACC" "G"
"PITCH" "DEG"
"15:48:54"
"03-15-1991"
10
8
6
4
2
0
-2
-4
-6
-8
0
1
2
3
4
5
6
7
8
9
10
A:\T15_OSN.PRN
"TIME" "secs"

FIGURE 4-4

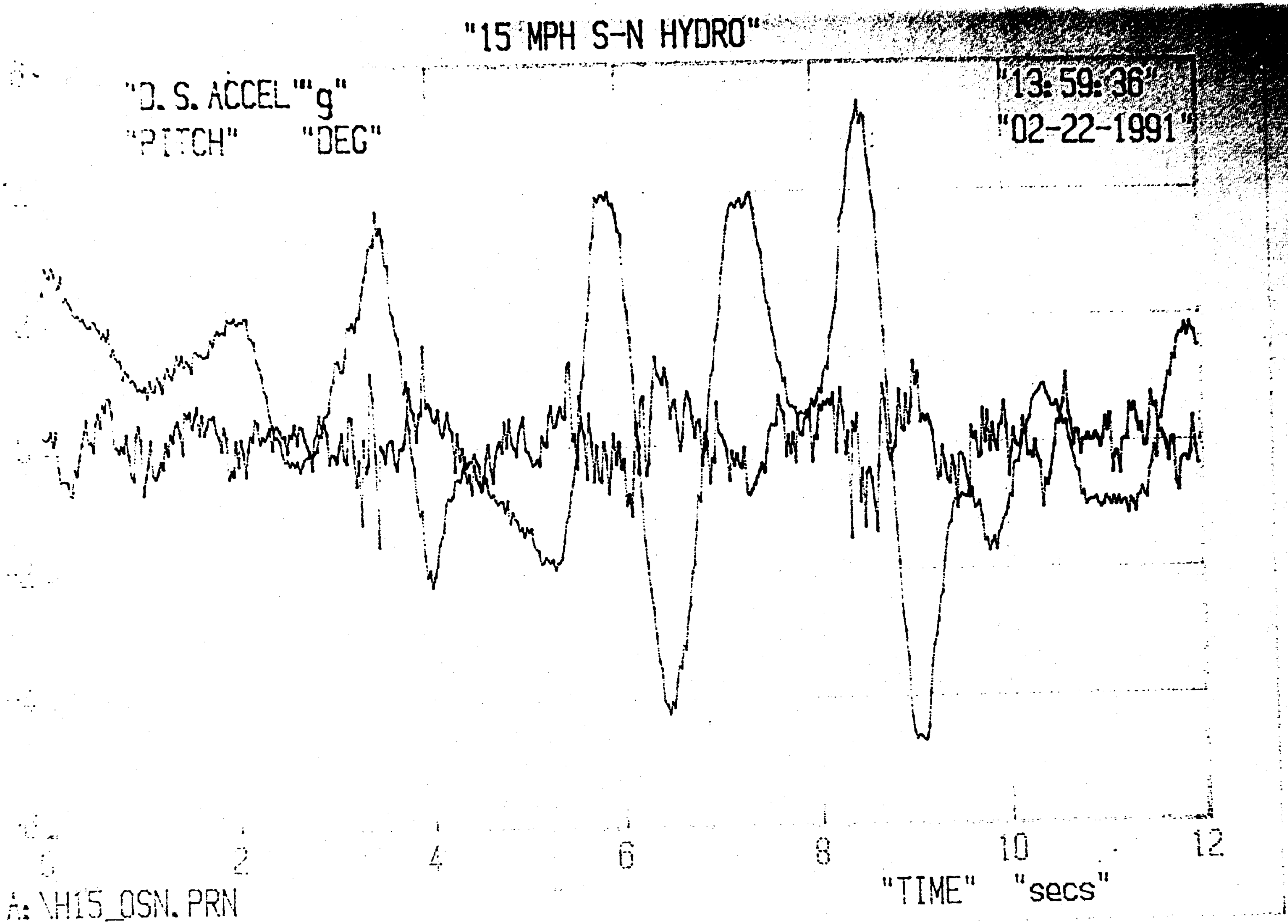

"15 MPH S-N HYDRO"
"D. S. ACCEL" "g"
"PITCH" "DEG"
"13:59:36"
"02-22-1991"
0
2
4
6
8
10
12
"TIME" "secs"
A:\H15_OSN.PRN

FIGURE 4-5

PEAK g'S TO DRIVER SEAT

CADILLAC GAGE

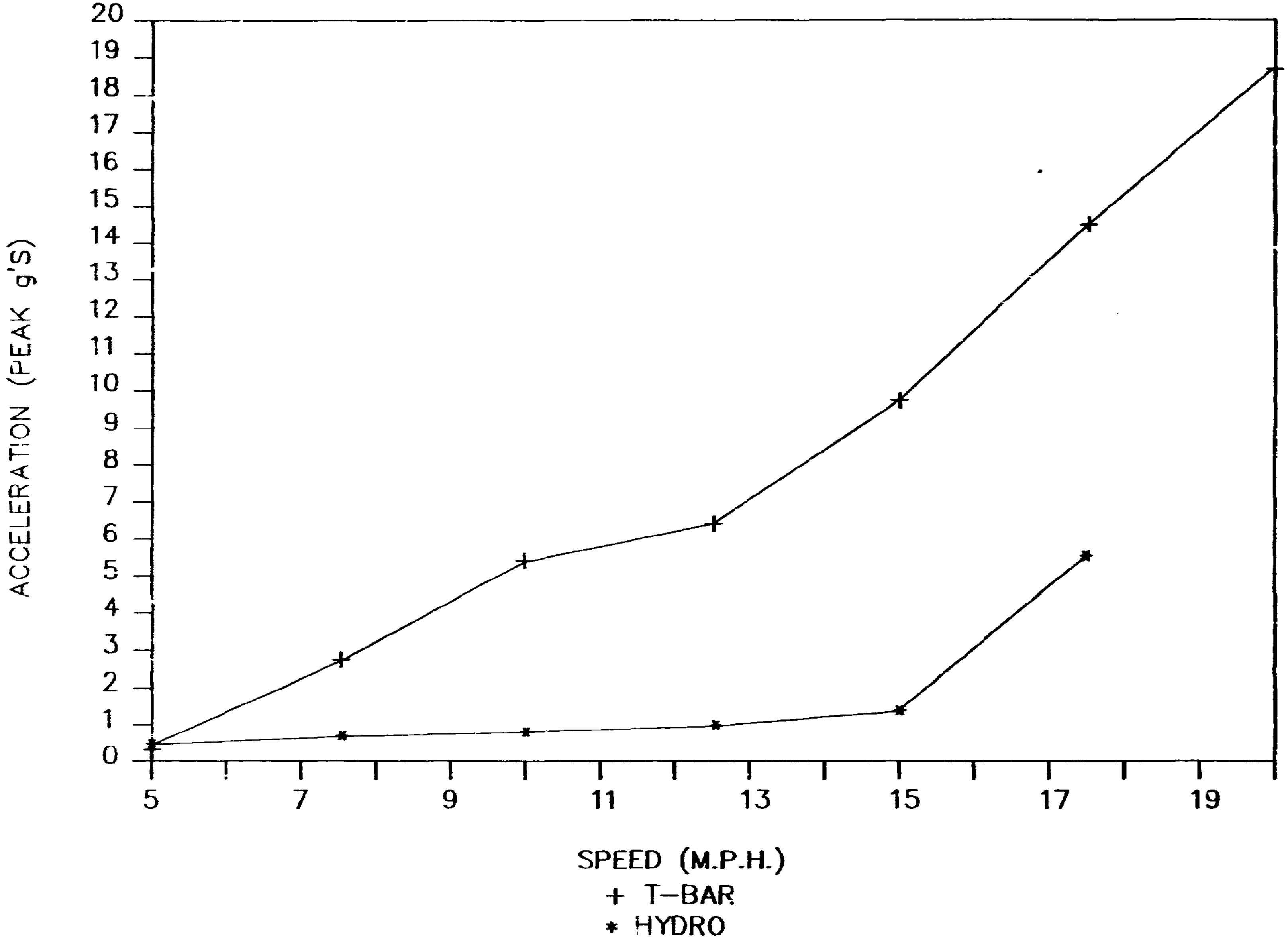


FIGURE 4-6

P—7 RIDE
POWER VS. SPEED

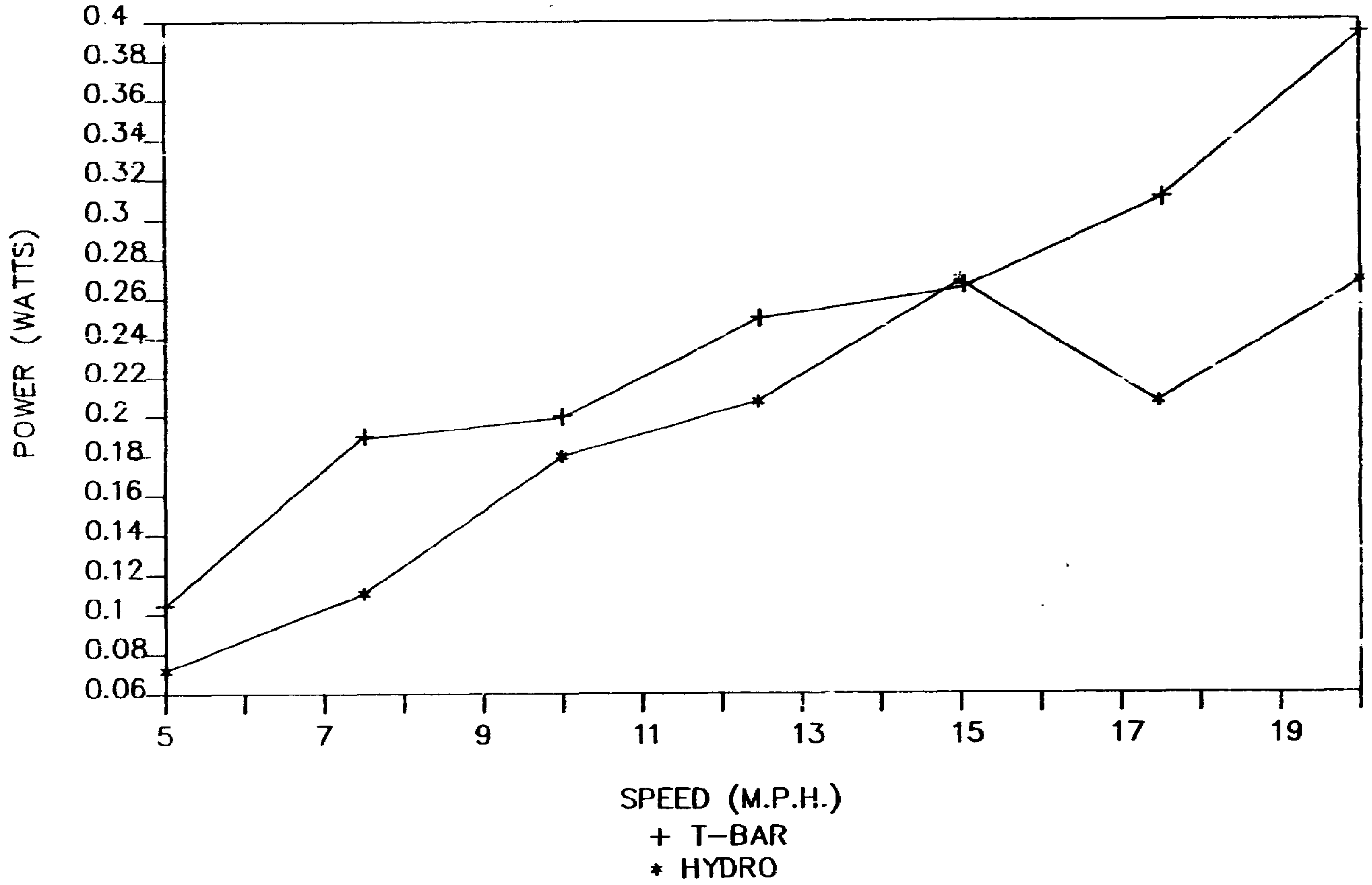


FIGURE 4-7

- Amphibious Compatibility
- Vehicle Handling Comparison
- Baseline Vehicle Requirements
- Design Requirements
- RAM-D Tests
- Towing Test

4.3.3.2 Test Results

The hydropneumatic suspension system (HSS) test vehicle successfully completed the following Phase 1a performance tests at vehicle weights of 53,500 lbs. and 59,100 lbs.:

- Amphibious Compatibility
- Vehicle Handling Comparison Tests
- Baseline Vehicle Requirements
- Slope Negotiation
- Pivot Steering
- Towing Tests

In addition, 75 miles of RAM-D testing was accumulated. Only 150 miles of cross-country hot weather testing (Phase 1b) were completed because of the low incidence of 100°F temperatures. An AVTB summary sheet of testing completed appears in Figure 4-8.

The basic scope of work and field support were completed as of 1 November 1990.

A Test Report has been submitted by AVTB to the Program Office (Direct Reporting Program Manager - Advanced Amphibious Assault) in January 1991. Findings from that report are not reflected in this document, due to unavailability of the report.

4.3.3.2.1 Problem Identification and Analysis

Initial vehicle field testing revealed the following problems : 1. ISU damper "hang-up", 2. Vehicle height and attitude affected by shifts in vehicle weight and CG location, 3. Unit torque cover bolts loosening during operation, 4. Crankcase dust seal failures, 5. Spindle-to-hull torque pins backing out of the spindle flange, and 6. Corrosion of charging ports and drain plugs. These are discussed in the sections below.

4.3.3.2.1.1 Damper "Hang-up"

During operations such as trench crossings, it was noticed that the ISU dampers were "hanging up" after going into the jounce position. Further investigation revealed that the internal hydraulic system of the ISU associated with the friction damper was not bleeding off rapidly enough after actuation to allow the roadwheels to drop quickly and maintain contact with the track. This occurrence restricted vehicle trench crossing. To facilitate damper bleed-off,

HYDROPNEUMATIC SUSPENSION SYSTEM (HSS) TEST

TESTING DONE SINCE RESTART 27 APR 90 BY 6 AUG 90 TEST PLAN				VEHICLE PX1210		VEHICLE P6	
PARAGRAPH		TEST DESCRIPTION	TASKED BY PM [illegible]	53,500 LBS	59,100 LBS	53,500 LBS	59,100 LBS
3.3.1		RIDE QUALITY: TROOP COMPARTMENT	X				
		DRIVER'S POSITION	X				
3.3.2		CROSS COUNTRY TEST COURSE TRANSIT TIME: TOTAL	X				
		OVER DIFFERENT TYPES OF TERRAIN	X				
3.3.3		AMPHIBIOUS COMPATIBILITY: EMBARK, DISEMBARK SHIP			X		X
		'DOGGING DOWN' EFFECTS			X		X
		TOWED ON AND OFF SHIP					
		SURF OPS			X		X
3.3.4		VEHICLE HANDLING COMPARISON TESTS: TOP SPEED	X	X	X	X	X
		ACCELERATE 0-30 MPH	X	X	X	X	X
		PANIC STOP W/O SKIDDING 30-0 MPH	X	X	X	X	X
		SLALOM COURSE	X				
		6 FOOT SURF OPS	X	NOT AVAILABLE	NOT AVAILABLE	NOT AVAILABLE	NOT AVAILABLE
		SMOOTH WATER TOP SPEED	X				
3.3.5		BASELINE VEHICLE REQUIREMENTS:					
	a.	TRENCH CROSSING TEST: 4' DEEP BY 8' WIDE	X	X	X	X	X
	b.	VERTICAL OBSTACLE TEST: 3' HIGH	X	X	X	X	X
	c.	CORROSION:		X	X		
	d.	CLIMATIC TESTING: HOT (100-125 °F): 3.3.1		X			
		3.3.2					
		3.3.4					
		3.3.5 a.					
		b.					
		e.					
		f.					
		3.3.6 a.					
		b.					
		c.					
		d.					
		e.					
		COLD (-25-0 °F): 3.3.1					
		3.3.2					
		3.3.4					
		3.3.5 a.					
		b.					
		e.					
		f.					
		3.3.6 a.					
		b.					
		c.					
		d.					
		e.					
	e.	SLOPE NEGOTIATION: 60%	X	X	X		
		40%	X	X	X		
	f.	PIVOT STEERING: HARD SURFACE, FAST	X	X	X		
		SLOW	X	X	X		
		SECONDARY ROAD, FAST	X	X	X		
		SLOW	X	X	X		
		PACKED SAND, FAST	X	X	X		
		SLOW	X	X	X		
		VEGETATED TERRAIN, FAST	X	NOT AVAILABLE	NOT AVAILABLE	NOT AVAILABLE	NOT AVAILABLE
		SLOW	X	NOT AVAILABLE	NOT AVAILABLE	NOT AVAILABLE	NOT AVAILABLE
	g.	MINE PLOW EVALUATION: 6000 LBS CARGO + PLOW; LCG					
		PLOWING					
	h.	NOISE MEASUREMENT: PAVED ROAD					
		LOOSE SAND					
		PACKED SAND					
		SECONDARY ROAD					
3.3.6		DESIGN REQUIREMENTS:					
	a.	FLUID AND GAS LEVEL CHECK:		X	X		
	b.	RIDE HEIGHT: MILES		X	X		
		TIME PARKED		X	X		
		DELTA AMBIENT TEMPERATURE ±10 °F		X	X		
	c.	RETURN ROLLER WEAR:		X	X		
	d.	ROADWHEEL / SUSPENSION UNIT INTERFERENCE:		X	X		
	e.	TRACK TENSION SETTING AND ADJUSTMENT:		X	X		
	f.	INSTALLATION AND REMOVAL OF SUSPENSION UNITS:	X				
		PRESSURIZED	X	NOT RECOMMENDED	NOT RECOMMENDED		
		UNPRESSURIZED	X	X	X		
		WITH HUB ATTACHED	X	NOT RECOMMENDED	NOT RECOMMENDED		
		WITHOUT HUB ATTACHED	X	X	X		
		OTHER USING MAINTENANCE CART	X	X	X		
	g.	SHORT TRACKING: (SEE SEPARATE TEST MATRIX)		UNITS CAN'T BE SWAPPED SIDE FOR SIDE			
3.3.7		RAM-D: (TRACK NORMALLY AND WITH INCIDENT REPORTS)		X	X		
		EVALUATE PROPOSED HSS TM		IN WORK			
3.3.8		TOWING TESTS: PX1210 TOWS P6, THEN P6 TOWS PX1210					
		LOOSE SAND WITH TOW BAR		X	X	X	X
		PACKED SAND WITH TOW BAR		X	X	X	X
		PAVED ROAD WITH TOW BAR		X	X	X	X
		CROSS COUNTRY WITH TOW BAR		X	X	X	X
		MUD / CLAY WITH TOW BAR		NOT AVAILABLE	NOT AVAILABLE	NOT AVAILABLE	NOT AVAILABLE
		VEGETATED TERRAIN WITH TOW BAR		NOT AVAILABLE	NOT AVAILABLE	NOT AVAILABLE	NOT AVAILABLE
		LOOSE SAND WITH TOW CABLES		X	X	X	X
		PACKED SAND WITH TOW CABLES		X	X	X	X
		PAVED ROADS WITH TOW CABLES		X	X	X	X
		CROSS COUNTRY WITH TOW CABLES		X	X	X	X
		MUD / CLAY WITH TOW CABLES		NOT AVAILABLE	NOT AVAILABLE	NOT AVAILABLE	NOT AVAILABLE
		VEGETATED TERRAIN WITH TOW CABLES		NOT AVAILABLE	NOT AVAILABLE	NOT AVAILABLE	NOT AVAILABLE
AVTB		TOP SPEED WITH SWITCHED POWER PACKS: ORIGINAL PACKS		20.0 MPH	18.75 MPH	23.08 MPH	25.0 MPH

FIGURE 4-8

relief valve clearances in the ISU's were increased from .0001 to .0028 inch. No further occurrences were noted, and the vehicle was able perform trench crossings without difficulty.

4.3.3.2.1.2 Vehicle Height and Attitude

Because the AAV7A1 vehicle is a cargo and troop carrying vehicle, large changes in vehicle weight and CG location are seen. During testing, this resulted in varying track tension and ground clearances, and impaired ride quality. See Appendix H for actual vehicle weights and corresponding CG's and ground clearances. To compensate for the weight changes, the rear station (3-6) ISU springs were stiffened by the addition of 300 cubic centimeters of oil. Charging pressures were not changed.

The stiffer rear springs improved the vehicle weight shift/ground clearance situation, but did not eliminate the problem. It was decided that two weights only would be used to complete the testing: 53,500 and 59,100 pounds. The Vehicle Test Plan was revised by DTRC to reflect this change. New load calculations were performed for the suspension system based on an average of these two weights. The spring charging values computed and subsequently used for the remainder of the testing were: 3,245 psi for Stations 1 and 2, and 1,975 psi for Stations 3 through 6.

4.3.3.2.1.3 Torque Cover Bolts

Loose torque cover bolts were an on-going occurrence during the course of the field testing. This was caused by the amount of flexing that the ISU's were undergoing. In an attempt to alleviate the problem, the bolts were fitted with lock tabs, but these did not have a significant effect. The proposed solution, to be incorporated into the subsequent FSD ISU design, is to provide larger bolts, a thicker torque cover, and more material in the area to give a stiffer roadarm.

4.3.3.2.1.4 Crankcase Dust Seal Failures

Another recurring problem with the HSS during the testing was the leakage of oil and the subsequent loss of spring and crankcase pressures. Early on, it was found during unit disassembly and repair that dirt and sand were getting past the crankcase dust seals and into the ISUs. The saltwater/sand environment that the vehicle was being exposed to was the initial cause of the seal failures. The salt corroded the steel sealing surface, introducing rust and pits, and thus creating a leak path for contamination to enter the crankcase of the ISU. Also, the oscillatory movement of the seal over the corroded surface accelerated the seal wear, which served to aid in allowing further contamination in. Eventually, the high pressure seals in the spring were contaminated, resulting in the spring's inability to hold a charge. Because a more successful seal configuration had not been found at the time, the repair of the units consisted of cleaning and resurfacing the crankcase seal area, and installing new seals of the same configuration. A Failure Analysis Report describing an incident of this type typical of those found during field testing can be found in Appendix I.

4.3.3.2.1.5 Spindle-to-Hull Torque Pins

Near the completion of the testing program, it was noted that the spindle-to-hull torque pin had begun to back out of the spindle flange in at least four (4) of the units. As with the loosening of the torque cover bolts, this was attributed to unit flexing during operation. A proposed solution is to utilize stepped pins.

4.3.3.2.1.6 Charging Port and Drain Plug Corrosion

It was also noted near the completion of testing that the charging valve protection plugs and drain plugs in the units had rusted and corroded, making it difficult to access these ports. The proposed solution to this problem is to use stainless steel valves, valve covers and plugs, and to incorporate o-ring seals into the covers and plugs that don't already use them.

4.3.3.2.1.7 Other Areas of Concern

During the course of the testing, DTRC and AVTB personnel identified several areas relating to the suspension system that warranted additional investigation. These were noted and are listed below:

- Short-tracking ability
- Removable wheel spindle
- Installation by a vehicle crew of 3
- Fieldable charging cart
- "Dog-bone" type road arm lifter

CGT has analyzed the feasibility of these items and has concluded that their accommodation does not present any major technical problems. These would be examined in further detail during the subsequent FSD design phase.

4.3.3.2.2 Proposed Improvements

Cadillac Gage has proposed several practical solutions to the problems encountered during the field testing for implementation into the current hardware. In addition, CGT has expended considerable effort in developing a modified 6K ISU design incorporating vehicle height/attitude maintenance and the choice of two proposed crankcase dust seal designs. This modified unit design is suggested for implementation into follow-on programs. The modifications for both current and future hardware are described in the following sections.

4.3.3.2.2.1 Vehicle Weight Change

Four different solutions to the weight shift/ground clearance problem have been proposed. Two of these can be implemented into existing hardware but do not completely correct the ground clearance situation. The third and fourth changes most completely address the problem, giving HSS configurations that comfortably meets the ground clearance requirements under a wide range of vehicle weights and CG's. The third proposed modification involves changing the internal geometry of the ISU. The fourth solution is the addition of a height maintenance system into the HSS. Therefore, these latter two proposals are designed for implementation into future systems.

For a good vehicle ride, the spring rate of the ISU should be low, or around one (1) cycle per second, at the static ride position. In tuning the system when originally installed on the vehicle, the tendency was toward ride performance, and therefore the rear springs were set up soft. This setup, however, was ineffective for maintaining the desired ground clearances when the GVW was varied; to accommodate this situation, the spring rate should be very high. The first solution increases the spring rate in the rear springs by adding oil to the ISUs, thus enabling these ISUs to operate at a higher spring rate and peak pressure. Also, the amount of jounce travel is reduced and the range of operation is shifted toward rebound as much as possible to increase the load slope. This solution, the easiest to implement, gives the differential ground clearance range desired but not at the correct position, and compromises vehicle ride. This modification was the course of action taken to complete the vehicle field testing at AVTB.

The second solution modifies the ISUs at stations 4 and 5 only, with the implementation of a grease-operated piston. This adaptation, which operates in a method similar to that used in a track tensioning system, provides ISUs so equipped with the ability to change their spring rates by changing the position of the piston. Figure 4-9 shows a cross-section of the ISU spring with a grease-operated piston. Figure 4-10 shows a comparison between achievable adiabatic spring rates.

The third solution involves lengthening the roadarm and modifying the ISU's internal geometry; the difference in roadarm length can be seen in the sketch shown in Figure 4-11. The system is mounted lower on the vehicle hull and road wheel spacing is rearranged, which is shown in Figure 4-12. These changes allow for an improved spring rate to accommodate vehicle weight shifts while maintaining desired jounce and rebound travel, additional space on the hull for an increased number and size of return rollers,

SECTION THROUGH SPRING
GREASE-OPERATED PISTON

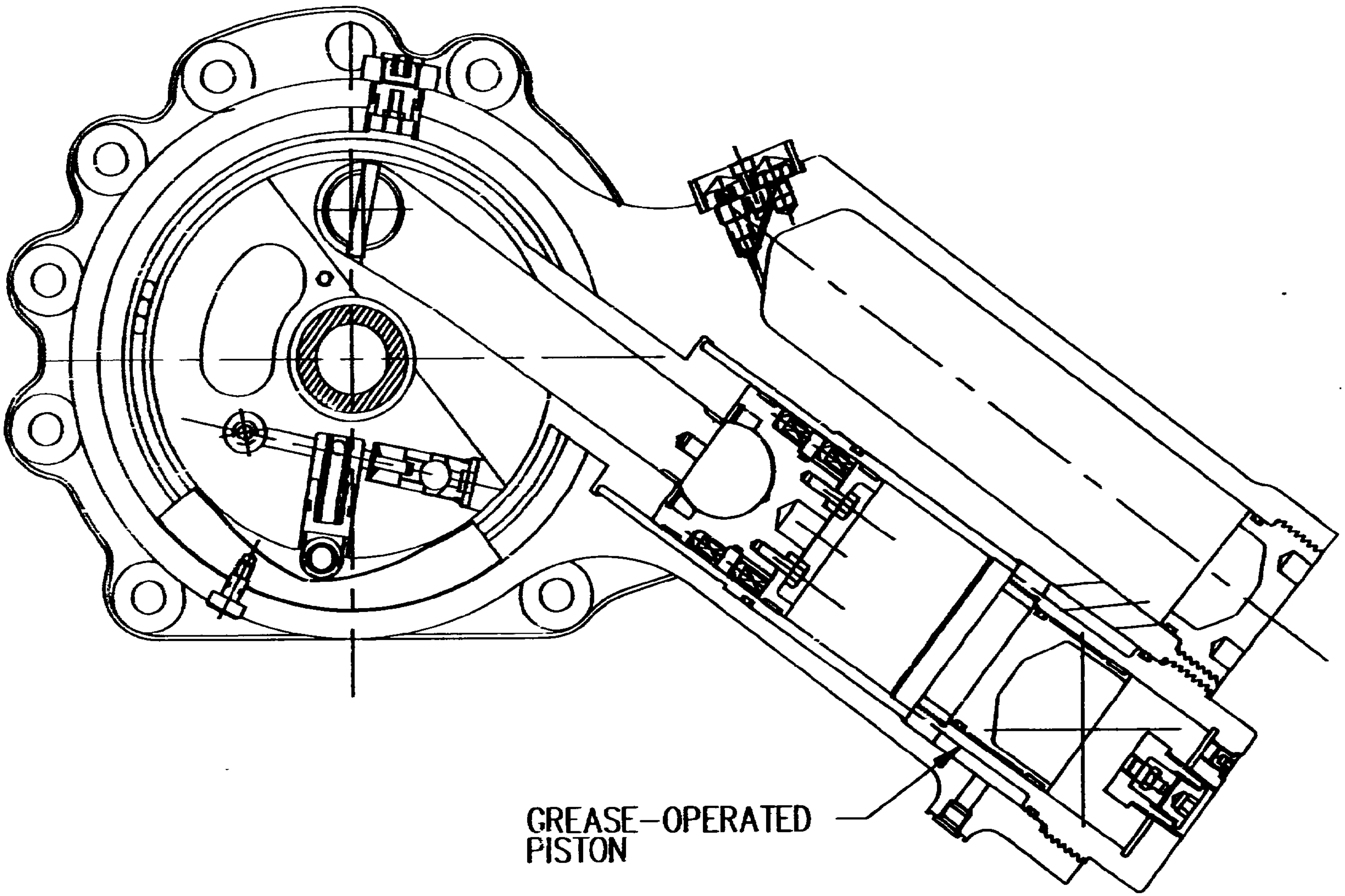
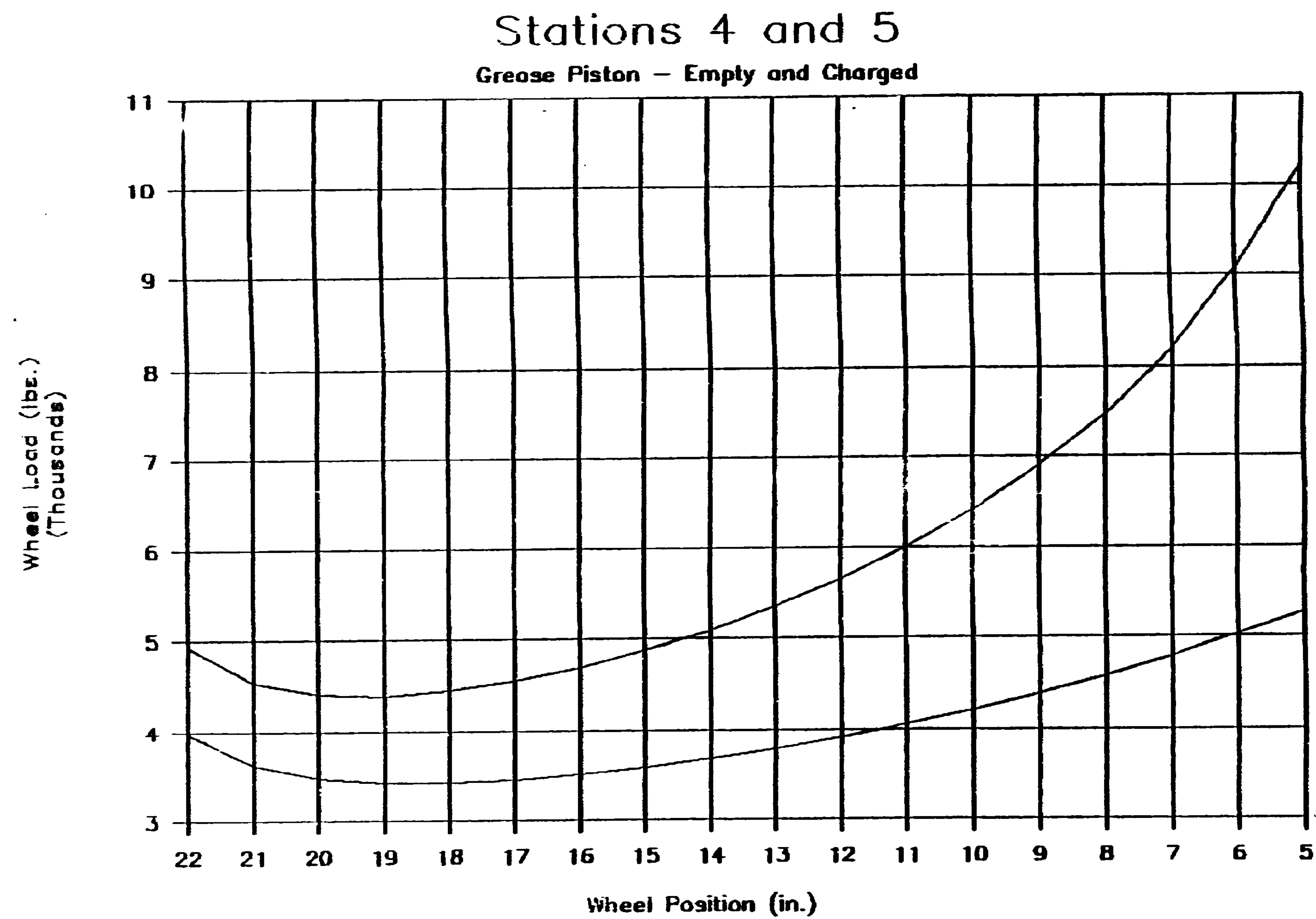


FIGURE 4-9



Stations 4 and 5
Grease Piston – Empty and Charged
11
10
9
8
7
6
5
4
3
Wheel Load (lbs.)
(Thousands)
22
21
20
19
18
17
16
15
14
13
12
11
10
9
8
7
6
5
Wheel Position (in.)

FIGURE 4-10

LONGER ROADARM LENGTH

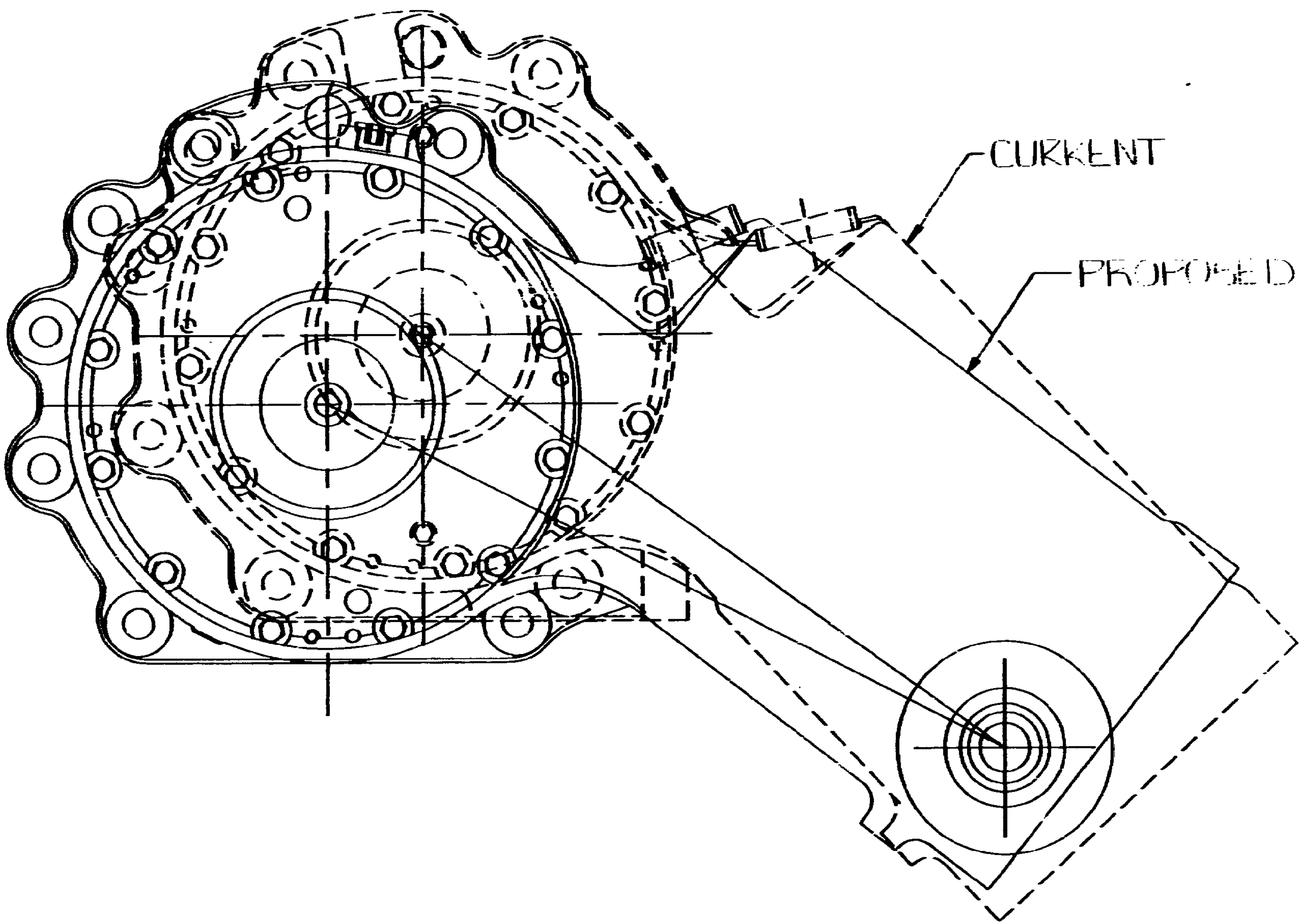


FIGURE 4-11

PROPOSED VEHICLE INSTALLATION

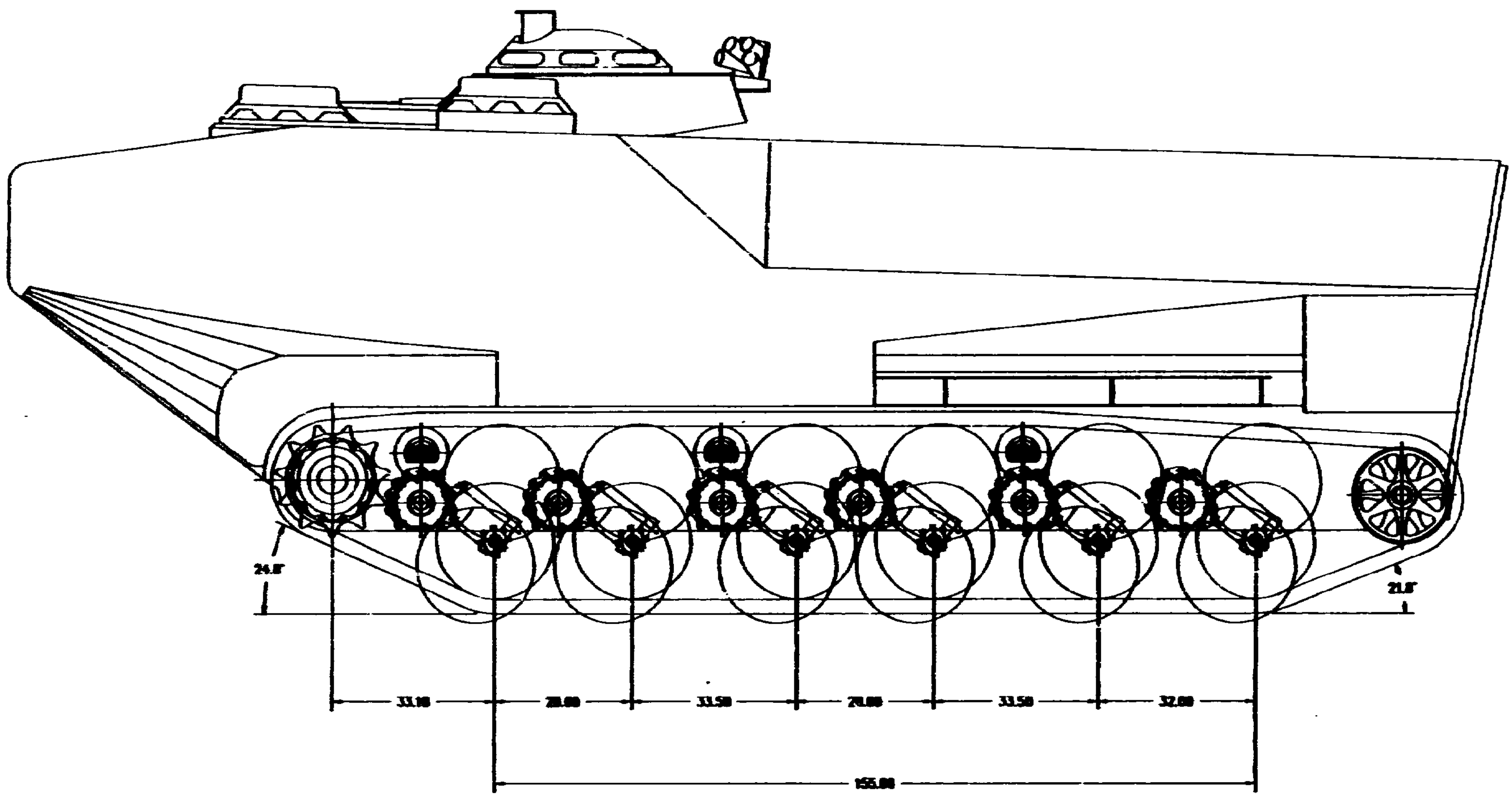


FIGURE 4-12

and lower trailing arm angles for improved vehicle handling and mobility. Figure 4-13 shows a comparison between the current and the improved adiabatic spring curves. Also, the improved load curve would make breaking track easier for repairs and maintenance. These changes can easily be implemented into follow-on production systems.

The fourth proposed solution is the addition of a height maintenance control system into the spring of the HSS. This system changes the volume of oil in the roadarm to compress the gas volume as required to maintain the static height/attitude of the vehicle relative to the terrain. This is accomplished with the use of a cam-operated control valve, a mechanical drive from the roadarm to the cam, and a connection to the roadarm from a fluid separator. Vehicle hydraulic power is used to supply the height maintenance system. This system enables the crew to set the suspension system to a predetermined ground clearance, to reset the vehicle to the initial ground clearance for changed gross vehicle weight, location of CG, and ambient temperature, to replace damaged suspension units, and to permit a nose down attitude when in hull defilade. Like the grease-operated piston proposal, the incorporation of the height maintenance system into the HSS configuration could also be accomplished during the course of a follow-on contract.

4.3.3.2.2.2 <u>Crankcase Seals</u>

Cadillac Gage has continued its test and development of crankcase dust seals. A custom design currently being tested has to date completed the equivalent of over 4,000 miles of operation, with no sign of leakage. In addition, the wear resistance of the mating roadarm surface has been increased through the use of an alternate material, heat treatment, and surface coating. This surface has also been made removable to allow for replacement if required. To further increase overall dust seal life, a pre-scraper has been incorporated into the configuration to prevent direct contact between dirt and water and the dust seal. CGT is confident that this design, which can be retrofitted into existing 6K hardward, will successfully fulfill the 6,000-mile minimum seal system requirement.

An off-the-shelf seal consisting of two high alloy, corrosion resistant steel rings, and two opposed Belleville washers made of nitrile elastomer has been incorporated into the modified 6K design. The two steel rings are precision-lapped and mated; the mating ring rotates against the stationary ring to create a leak-proof seal. The surfaces are pressed together by the Belleville washers, which provide uniform face loading and sealing at the inner and outer diameters. This configuration is similar to seals currently used in the roadwheel hubs and roadarms on the P-7 vehicle. Because of the increased space claim required for this seal, it has been planned for use in future hardware.

Stations 3 thru 6

Current and "New" PX 12 Configuration

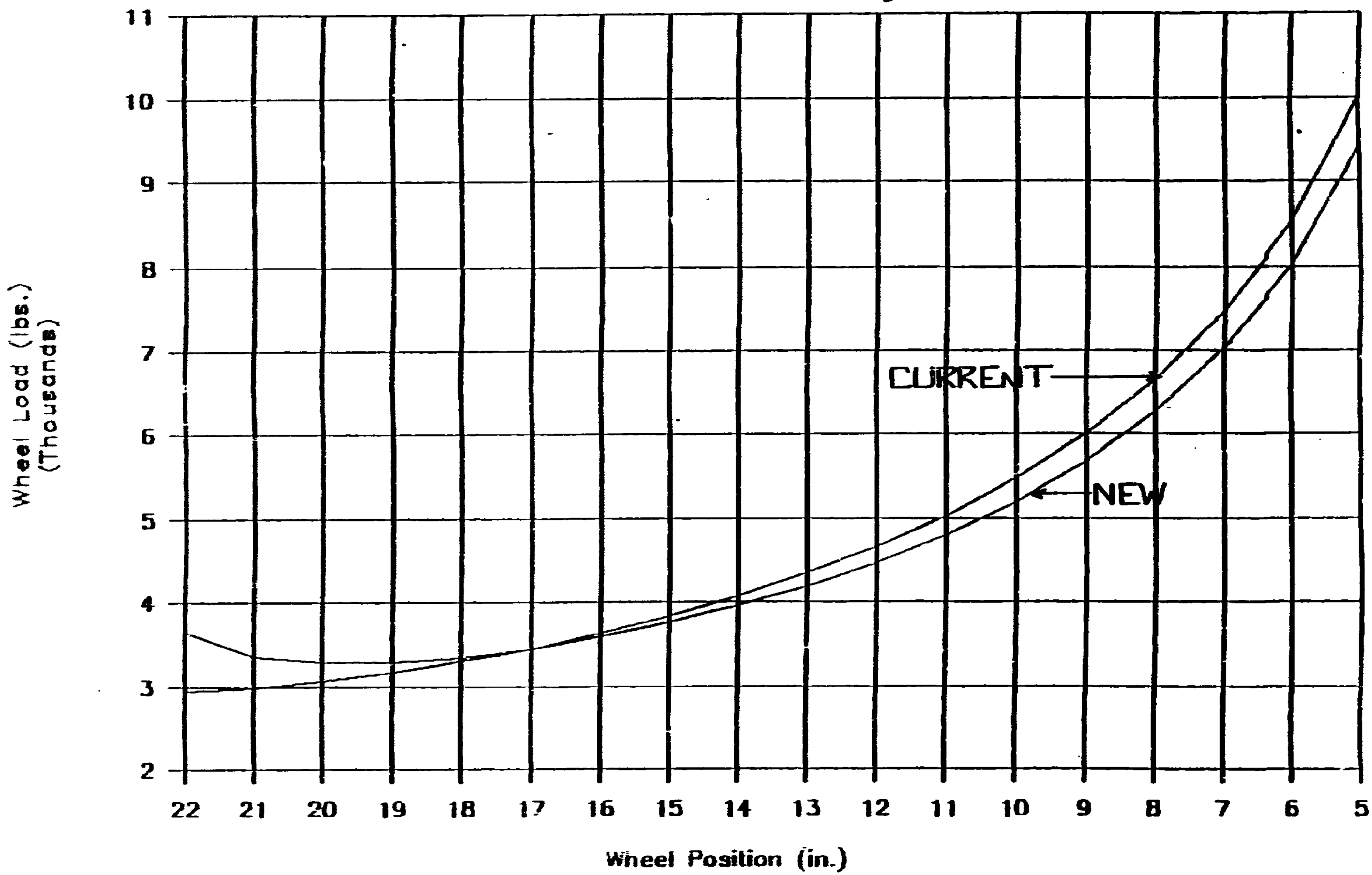


FIGURE 4-13

4.3.3.2.2.3 Torque Cover Bolts

The loosening of the bolts in the torque cover occurred because of excessive bending and flexing of the roadarm relative to the cover. The solution to this problem involves an increase of material in this area to stiffen the roadarm, with the addition of a thicker torque cover and larger bolts.

4.3.3.2.2.4 Spindle-to-Hull Pins

The backing out of the torque pins occurred because of flexing of the spindle relative to the vehicle hull. The utilization of either stepped pins or a blind torque pin hole would alleviate this problem.

5.0 CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion

The 6K hydropneumatic suspension system successfully fulfilled the objective of providing a system which improved ride characteristics and increased interior volume for the AAV-7A1 vehicle. Subsequent vehicle field testing in a sea water/sand environment provided test conditions not available in a laboratory situation, and revealed areas in the system where improvements and modifications were necessary. The implementation of these modifications, which have been outlined and discussed in the above sections, coupled with the appropriate field testing, would ultimately provide the Marine Corps with a reliable, durable, and easily-maintainable hydropneumatic suspension system.

5.2 Recommendations

It is CGT's recommendation that the Marine Corps continue its evaluation of the hydropneumatic suspension system. This would include providing support for the incorporation of the suggested modifications into the existing prototype system to eliminate anomalies discovered during field testing, and then continuing with testing at AVTB to accumulate the remainder of the RAM-D mileage originally cited in the Vehicle Test Plan. The release of the 6K Full Scale Development (FSD) Request for Proposal (RFP) would be contingent upon the successful completion of the testing. The modifications incorporated into the FSD design address the issues noted below:

- Track replacement and short-tracking would be much easier to accomplish due to the improved unit geometry and spring rate.

- The use of improved crankcase seals would eliminate external leakage and internal contamination, thus alleviating spring-to-crankcase nitrogen leaking.

- Vehicle weight shifts would be accomodated with the improved unit geometry and spring rate.

- A fieldable charging cart and "dog-bone" type road arm lifter would allow for easy maintenance.

- Increased size and number of support rollers would reduce wear on these components, thus allowing for increased track support.

This effort would result in an external suspension system that would greatly enhance the performance characteristics of the AAV-7A1 vehicle, as well as benefit the entire Advanced Assault Amphibious Vehicle (AAAV) program.

APPENDIX A

HSS OPERATION AND MAINTENANCE MANUAL

AMS/721/M5-RB89303

5 October 1989

OPERATION AND MAINTENANCE MANUAL

for

HYDROPNEUMATIC SUSPENSION SYSTEM

Installed on

P-7 AMPHIBIOUS ASSAULT VEHICLE

David Taylor Research Center

Contract No. N00167-88-C-0024

INDEX

1.1 INTRODUCTION

Under the terms of David Taylor Research Center (DTRC) Contract N00167-88-C-0024, Cadillac Gage Textron (CGT) has supplied to the United States Marine Corps at Camp Pendelton, California a Hydropneumatic Suspension System (HSS) installed on a Government furnished P-7 Amphibious Assault Vehicle (Figure 1-1). The modified vehicle is scheduled for performance and endurance testing by the Marine Corps in the near future. This testing will be supported under contract by technical personnel of CGT.

This manual is intended to provide sufficient information to allow Marine Corp personnel to operate and maintain the suspension system during the lengthy test program scheduled. A suggested maintenance philosophy and schedule for checking of gas pressures and oil levels in the suspension units and the removal and replacement of roadwheels, hubs, track rollers and suspension units will be covered in detail. Information concerning auxiliary maintenance support equipment supplied with the vehicle is also provided.

Repair and overhaul of the individual suspension units (Figure 1-2) will not be covered as CGT is committed to perform with its own personnel and facility any work of this type that might be necessary during the course of the test program.

2.1 THE HYDROPNEUMATIC SUSPENSION SYSTEM

In the typical tracked vehicle the weight of the hull is supported by a group of road wheels (typically from 5 to 7 per vehicle side) which directly engage the track and which are attached to the hull through a mechanical spring system. The spring system allows vertical motion of the hull relative to the ground while supporting its weight at an average nominal height above the ground. More often than not, the spring will be of rotary torsion bar configuration with the bar being arranged transversely across the vehicle hull and anchored near the side of the hull opposite the desired spring motion. For at least some, if

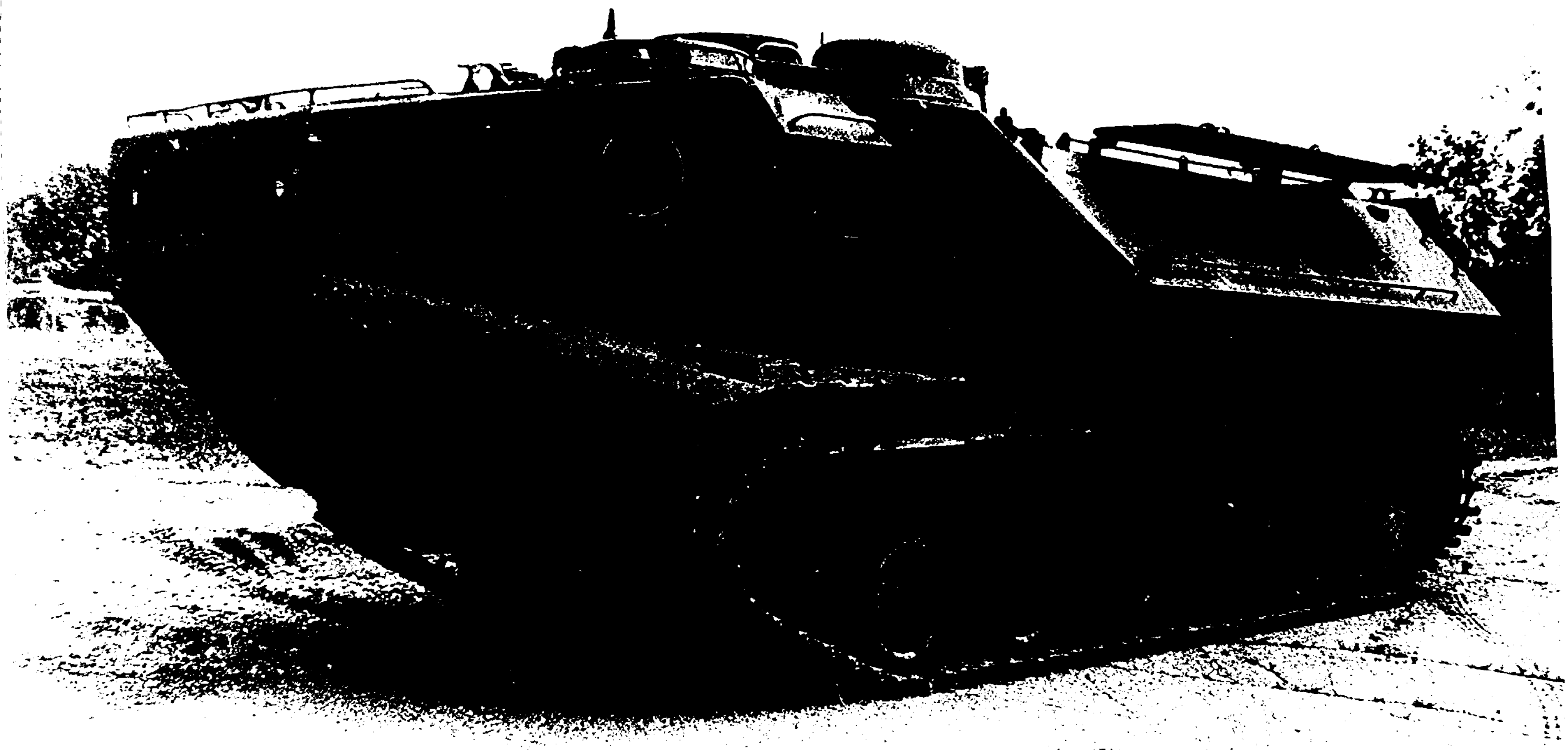


FIGURE 1-1

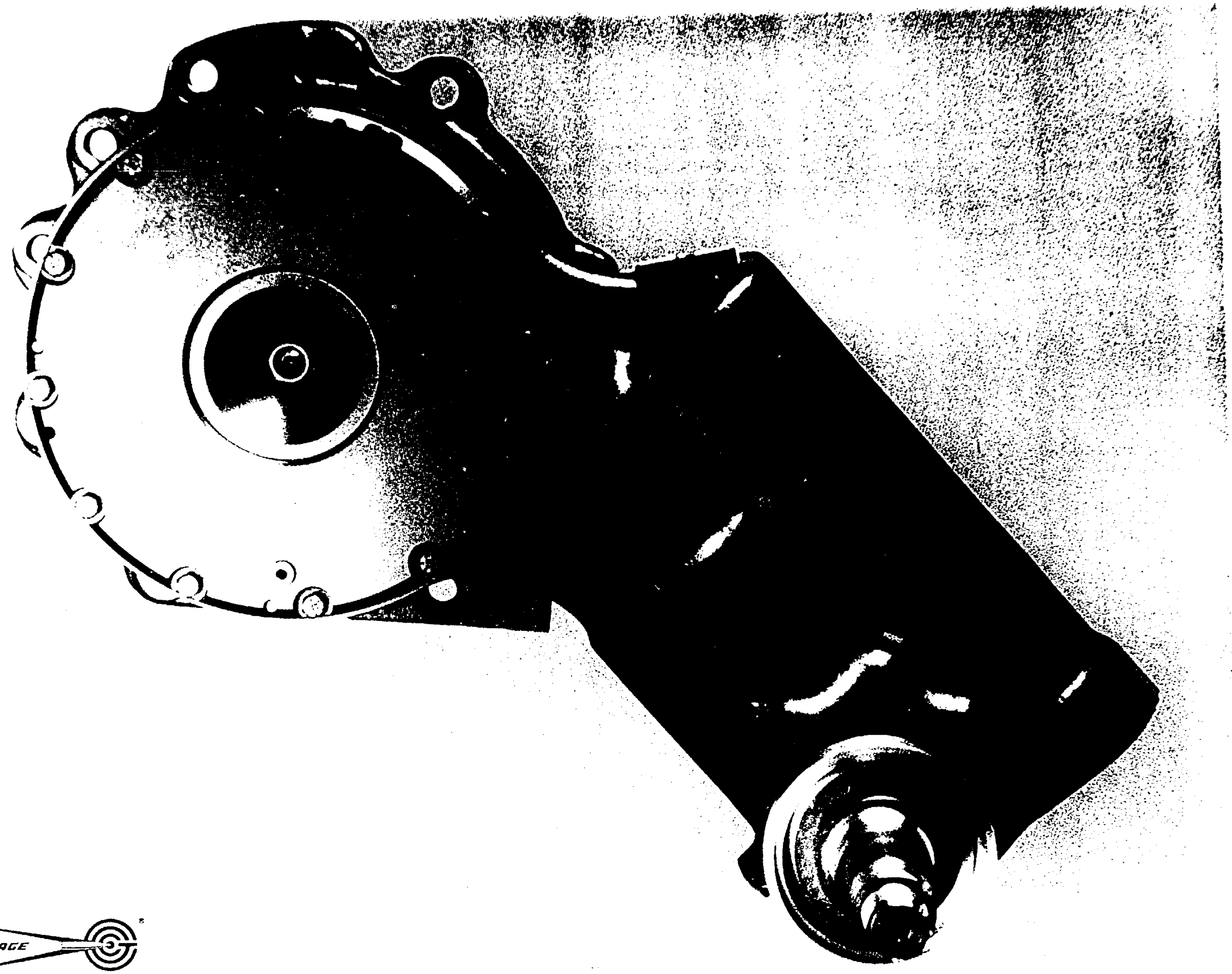


FIGURE 1-2

not all, of the sprung wheel stations there will typically be provided some form of damping to force motion of the selected system to damp out quickly after terrain inputs. This damping may be in either viscous or frictional form.

The HSS is no different philosophically than the mechanical system just described. The primary physical difference comes about in the method of achieving the spring characteristic which supports the hull with respect to the roadwheel set. It also differs from traditional suspension hardware in that the desired damping is integrally incorporated into the suspension unit as opposed to existing in the form of a separate "shock absorber".

Figure 2-1 will be of assistance in understanding the operation of the specific suspension system under discussion here. The figure is a side elevation cross section of one of the individual suspension units used on the P-7 vehicle. All twelve (12) units installed are functionally identical, differing only in their assigned pre-charge pressures as a function of their location on the vehicle.

The suspension unit is rigidly attached to the hull by mounting bolts inserted through the mounting flange of the spindle (1). A pair of large roller bearings (2) rotatably support the roadarm (3) with respect to the spindle and the roadarm is thus free to rotate in the plane of the drawing as shown. The roadwheel (4) (shown here only in phantom) is rotatably attached to the roadarm in turn by means of a wheel spindle not seen in this section, but located at (5). As a result, any external load applied to the roadwheel will be transmitted directly to the road arm through the wheel spindle. A sealing piston (6) floated in a cylindrical bore of the roadarm is attached by means of a connecting bar (7) to a pivot point (8) The pivot point is integral with the spindle (1) and thus is stationary with respect to the vehicle hull at all times. This being the case, forced rotation of roadarm (3) about bearing set (2) causes relative motion of the piston in its bore and an

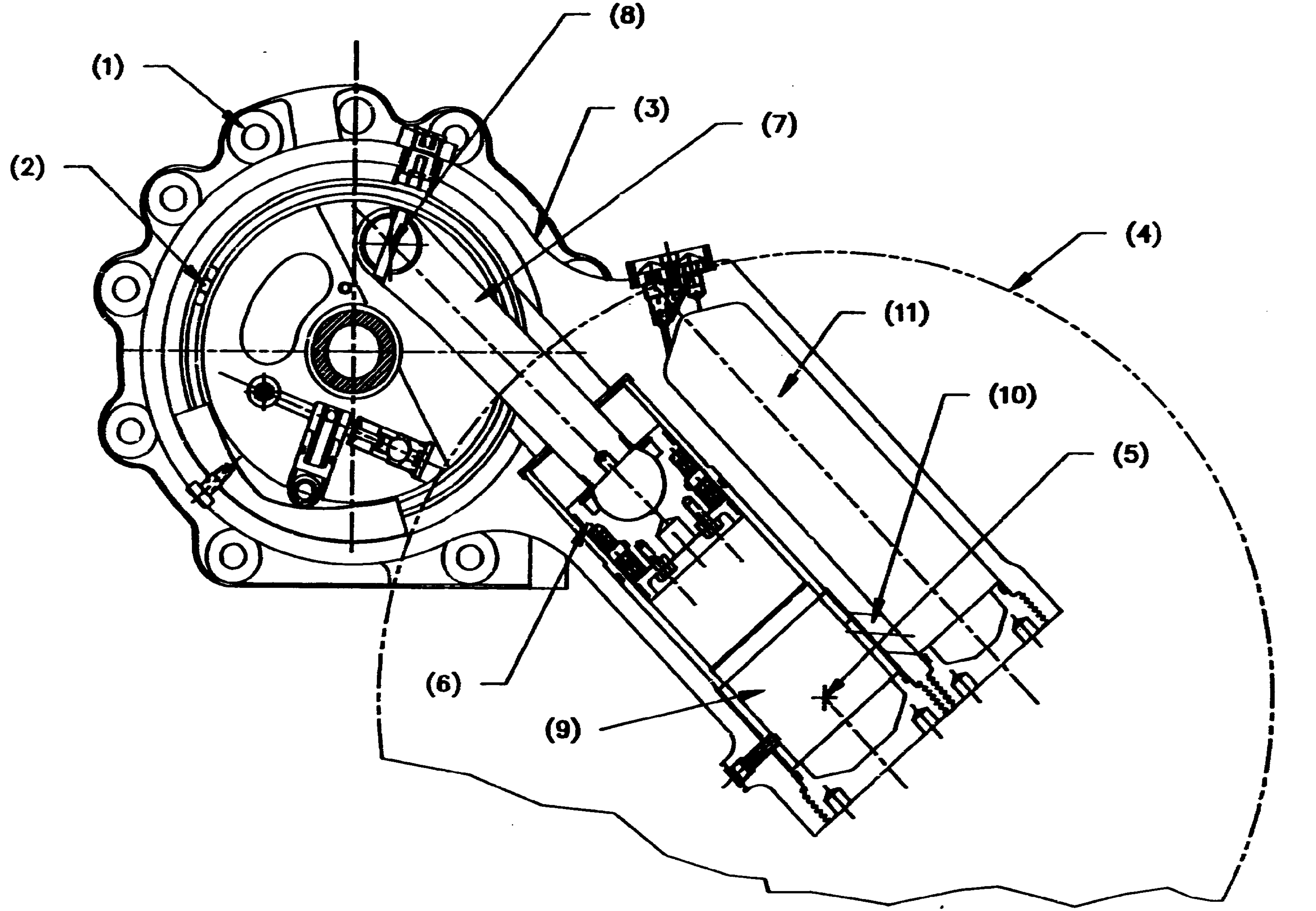


FIGURE 2–1

attendant change in the volume of chamber (9). Rotation of the roadarm in the counter clockwise direction causes volume (9) to be reduced. Similarly, rotation in the clockwise direction causes this volume to be expanded. Volume (9) is in turn connected by a passage (10) to volume (11). In operation, volume (9) is entirely filled with liquid. Volume (11) is partially filled with liquid at its lower right end while the remaining upper portion of the volume is filled with nitrogen gas.

The oil contained within the chamber area is relatively incompressible, but the nitrogen gas is not. Rotation of the roadarm therefore causes a large percentage change in the volume of the nitrogen gas while leaving the fluid volume relatively unaffected. The result is a dramatically changing pressure as a function of arm rotation within the chamber area. This variable pressure is directly applied to the piston and this in turn produces a variable torque at the roadarm. The roadarm, then, appears to be driven by a spring just as if it were used in conjunction with a torsion bar, except that the spring action is developed by virtue of compressibility of a gas rather than by the stress developed in the torsion bar.

It can be seen that the load produced at any point in the rotation of the roadarm can be altered by changing the pressure in the gas chamber at that location. Further, the slope or rate of the spring can be modified by changing the volume of fluid in the chambers and thus altering the compression ratio of the nitrogen gas. Changing the pre-load by changing the pressure is somewhat analogous to "clocking" the initial pre-load point of the torsion bar. Changing the rate of the spring by altering the fluid volume is equivalent to changing the length and/or diameter of the torsion bar, although such a change to the torsion bar is rarely done in practice due to practical physical restrictions.

The damping mechanism of the suspension unit can be seen in Figure 2-2, an end elevation cross section. A series of friction discs (1) form the

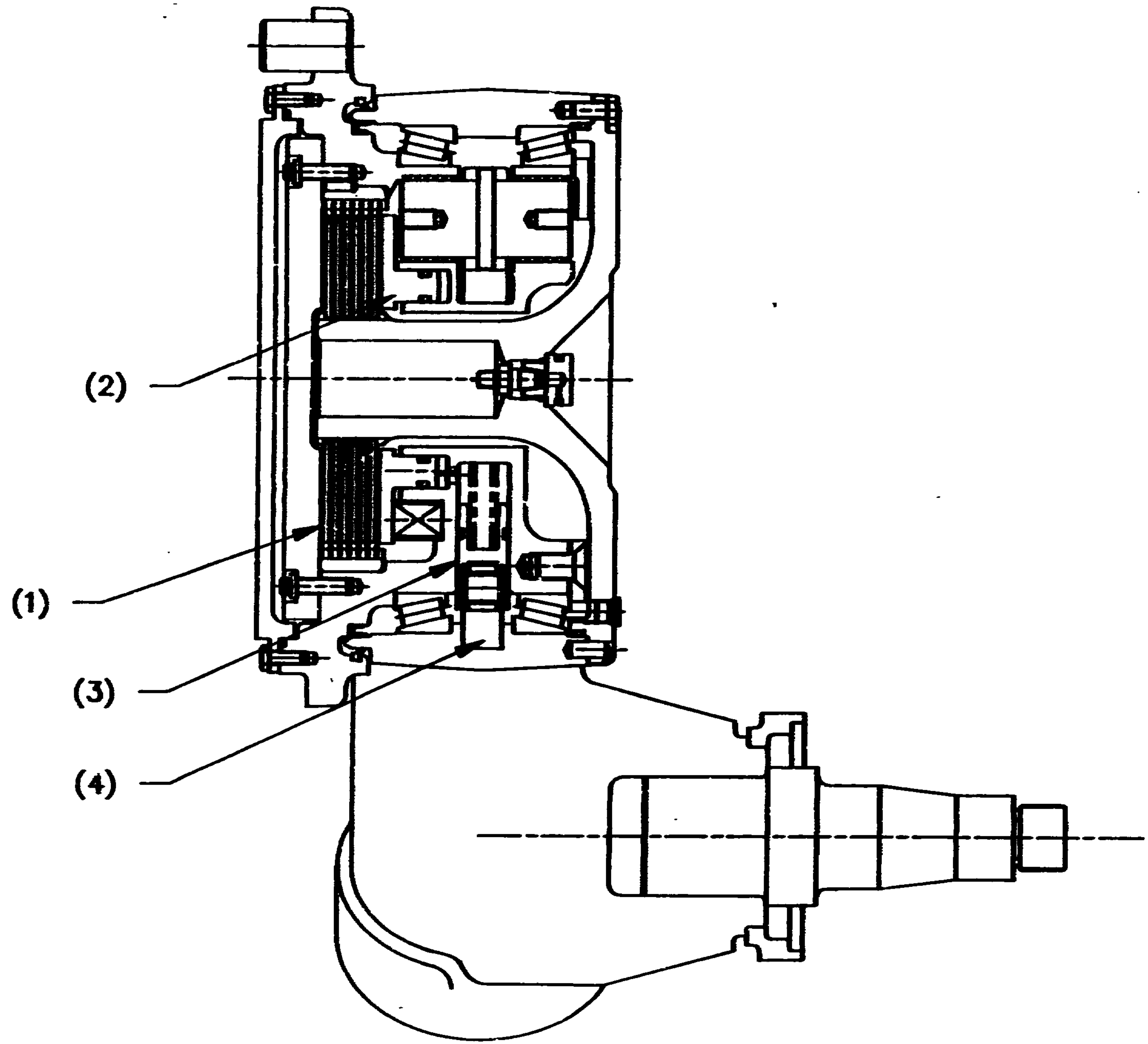


FIGURE 2–2

basic damping element. The discs are so arranged that one is externally splined so as to remain rotationally stationary with respect the suspension unit spindle, the next internally splined so as to rotate with the roadarm. The third is, like the first, fixed to the spindle, and so on. A normal force is applied to the stack and this provides damping friction to oppose relative rotation of the spindle and roadarm. A large degree of versatility in the damping characteristics is made possible by utilizing a hydraulic means to apply the normal force to the friction discs. This is done by the application of hydraulic pressure to toroidal piston (2), forcing it against the plates. The pressure is developed through the action of piston pump (3) installed in the stationary spindle. The piston pump is driven by cam (4) which is mounted to the roadarm and rotates with it. By controlling the position, rise rate and dwell of the cam as well as the peak pressure developed in the pump by means of a relief valve, it is possible to provide an almost endless variety of damping characteristics in the suspension unit. The characteristic currently used is the result of an extensive amount of operational experience with the test vehicle. As earlier mentioned, all twelve (12) suspension units provided with the vehicle are functionally identical and in consequence all stations exhibit the damped characteristic.

Since the HSS uses high pressure nitrogen gas as well as hydraulic fluid in its operation, it follows that some form of unusual maintenance support equipment must be required. This is indeed the case and CGT has supplied with the vehicle a charging cart which makes available means to add high and low pressure gas as well as clean fluid to the suspension units and to check the pressures in their chambers. Provision is also made on the cart to lift and handle the suspension units during removal and replacement operations. In addition, a roadwheel jack specifically adapted to the physical characteristics of the suspension units has been included with the equipment shipped with the vehicle. These items will be discussed in detail in a later section.

3.1 MAINTENANCE PHILOSOPHY

The HSS has been designed for long service life and may be expected to equal or exceed the endurance characteristic of the vehicle itself in terms of operational time between major overhauls. The design of the individual suspension components is such that very little routine maintenance is required or indeed even possible. The suspension units are totally enclosed and sealed so that fluid levels within the units are expected to require no maintenance for the life of the units between overhauls. Some minor loss of nitrogen gas may be expected over time and it is in this area alone that routine maintenance can and will be performed.

Each suspension unit contains two distinct sections where specific volumes of fluid and pressures of gas are maintained. As the total volumes in these two areas change as a function of roadarm position (one rises as the other falls), it is necessary to define a particular position at which measurements are made. This position is known as the "static" position of the roadarm and it corresponds to that position achieved when the suspension unit is functioning on the vehicle at normal vehicle height. In the case of the HSS equipped P-7, standard ground clearance has been established as 17 inches and suspension unit "static" position corresponds to this height.

At the static position, the crank case of the suspension unit is filled to its horizontal center line with fluid and topped off with a low pressure charge of dry nitrogen to assist in excluding dust and dirt from the unit. A nominal charge of 60 psi at a standard temperature condition of 70°F is usually used. The fluid in the crank case serves several purposes. It forms the reservoir source for the piston pump which supplies fluid pressure to load the friction disk assembly to achieve damping in the unit. It acts as a lubricant for the friction disks themselves. It further acts as a lubricant for the major roller bearings which mount the roadarm to the spindle. The fluid itself can be expected to last the overhaul life of the unit and should require no replenishment during that time. Any substantial external leakage which depletes the level of the crank case oil should be considered as a failure requiring suspension unit repair. Note that a relief valve is utilized as an emergency overflow device for the crank case and that under conditions of severe temperature change and vehicle usage, it is remotely possible that small amounts of fluid leakage may occur at the relief valve, which is positioned at the center of the front cover of the suspension unit. Minor amounts of leakage so witnessed under extreme conditions and later disappearing when conditions become less severe can be discounted as presenting no cause for concern.

The high pressure chamber of the suspension unit is charged at original assembly with a quantity of oil dependent upon the desired spring characteristic of the unit. A nitrogen gas charge is then placed on top of this oil charge at installation. The pressure level of this gas charge is dependent upon the vehicle weight and center of gravity (CG) location. As with the crank case, the oil content of the high pressure chamber may be expected to remain stable for the overhaul life of the suspension unit and no maintenance in this regard is required. Some minor amounts of gas leakage may be anticipated and it can be occasionally necessary to top off the gas charge.

The HSS equipped P-7 vehicle, as shipped by CGT and ballasted with materials supplied by DTRC, weighed in at just about 50,000 pounds, with full fuel load. Corner weight measurements showed the CG at 96.0 inches behind the final drive (Station 196.0). For this weight and CG condition, calculations showed the proper values of pre-charge for the suspension units at static condition to be:

Stations 1 & 2 (each side of the vehicle)	3,000 psi
Stations 3, 4, 5, 6 (each side of the vehicle)	1,750 psi

These pre-charge pressures correspond to a vehicle height of 17 inches and these were the pressures that were used when the vehicle was shipped. It should be realized that any large and relatively permanent change to vehicle weight and CG location should probably be accompanied by an equivalent modification to unit pre-charge pressures. These can be easily calculated for any given case. This is not to imply that a change in static pressure is necessary for every alteration in weight and CG any more than would be the case with torsion bar suspension. As will become apparent with experience, considerable changes in weight and CG locations can be accommodated without significant attitude change in the vehicle.

3.2 MAINTENANCE SCHEDULE

The following is suggested as a maintenance schedule for the P-7 vehicle equipped with hydropneumatic suspension:

3.2.1 Daily, or before vehicle use:

3.2.1.1 Visually check for evidence of leakage at each suspension unit. If leakage is noted, clean up the area and continue to observe the unit for signs of ongoing leakage. Continued evidence of leakage should be considered as cause to remove the suspension unit for depot service.

3.2.1.2 Establish convenient locations on the vehicle to check for height at each of the four corners corresponding to a hull clearance of 17 inches on level ground. Bring the vehicle to a free rolling stop and check vehicle attitude by scaling the previously established locations. If height is out of specification by more than 1" at any corner, check for "weak" suspension unit by lifting with a track bar. If an obviously defective unit is noted, replace at first opportunity. Otherwise, perform the tests of 3.2.2 at the earliest reasonable opportunity to establish the cause of the out-of-level condition.

3.2.2 Semi-annually, or at 500 hour operating intervals, perform a check per 3.2.2.1, 3.2.2.2 and 3.2.2.3.

The requirements of 3.2.2 must be performed with vehicle located on flat terrain and with the hull situated at the specified 17 inch ground clearance. If necessary, jacking must be used to accomplished this condition. In addition, the vehicle must be idle for at least 8 hours to allow temperatures to stabilize and to minimize foaming before the pressure checks are made.

Gas pressures in crank case and high pressure chambers will necessarily change as a function of ambient temperature. The following table may be used as a correction factor on the pressures checked in 3.2.2.1.

AMBIENT TEMP. °F:	MULTIPLE REQUIRED PRESSURE BY:
-20°	0.830
-10°	0.849
0°	0.868
10°	0.887
20°	0.906
30°	0.925
40°	0.943
50°	0.962
60°	0.981
70°	1.000

AMBIENT TEMP. °F:	MULTIPLE REQUIRED PRESSURE BY:
80°	1.019
90°	1.038
100°	1.057
110°	1.075
120°	1.094

3.2.2.1 Check static gas spring pressure at each suspension unit per procedure of 5.1. If any are found to be more than 5% outside the prescribed value, re-charge to the proper level per the procedure. A variation from the required pressure of more than 20% should be considered as cause to remove the suspension unit for depot service.

3.2.2.2 Check crankcase fluid level in all suspension units per method described in Section 5.2.

3.2.2.3 Charge crankcase pressures in all suspension units per method described in Section 5.3.

4.1 CHARGING CART/ROADWHEEL JACK

The charging cart (Figure 4-1) provided with the HSS equipped P-7 vehicle is designed to provide several features in terms of maintaining the suspension system:

- A means of checking and replenishing the high pressure gas supply in the suspension unit spring chamber.
- A means of checking and replenisning the low pressure gas supply in the suspension unit crank case.

- A means to provide clean, filtered fluid for replenishment of spring and crankcase of the suspension unit in the event of minor overhaul.
- A lifting means to assist in the removal and replacement of suspension units from the vehicle hull.

The charging cart is based upon a commercially available steel mill cart of 30 inch x 60 inch platform dimension utilizing pneumatic tires and a steerable tongue at the front of the cart. Mounted on the cart bed are a pair of channels suitable for accommodating two high pressure gas tanks which rest in a near horizontal position. On the center of the bed is an anchor for a hydraulic cylinder, the movable end of which attaches to a lift frame pivoted near the rear end of the cart bed. Longitudinally mounted on this lift frame is a slidable tongue. Motion of the cylinder provides a vertical lift at the end of the tongue, which is supplied with a bolt to be used in conjunction with a lifting eye. A manually operated hydraulic pump mounted above one of the cylinders provides the motive power to operate the lift cylinder.

The upper superstructure which mounts the manual pump also makes provision for a large storage box with removable cover. This box contains the necessary hoses and instrumentation for the operation of the charging cart. At one side of the box is mounted an air operated gas booster assembly whose function is to accept gas from the nitrogen tanks and boost the pressure of the gas to a level suitable for entry into the suspension unit spring. Above the booster is mounted a low pressure gas regulator which serves to provide gas to the suspension unit crank case and to pressurize the oil supply to make fluid available for replenishment of spring and crankcase in the event of minor overhaul.

The terminations of the three hoses contained in the storage box may be seen in Figure 4-2, The leftmost termination is that for low pressure

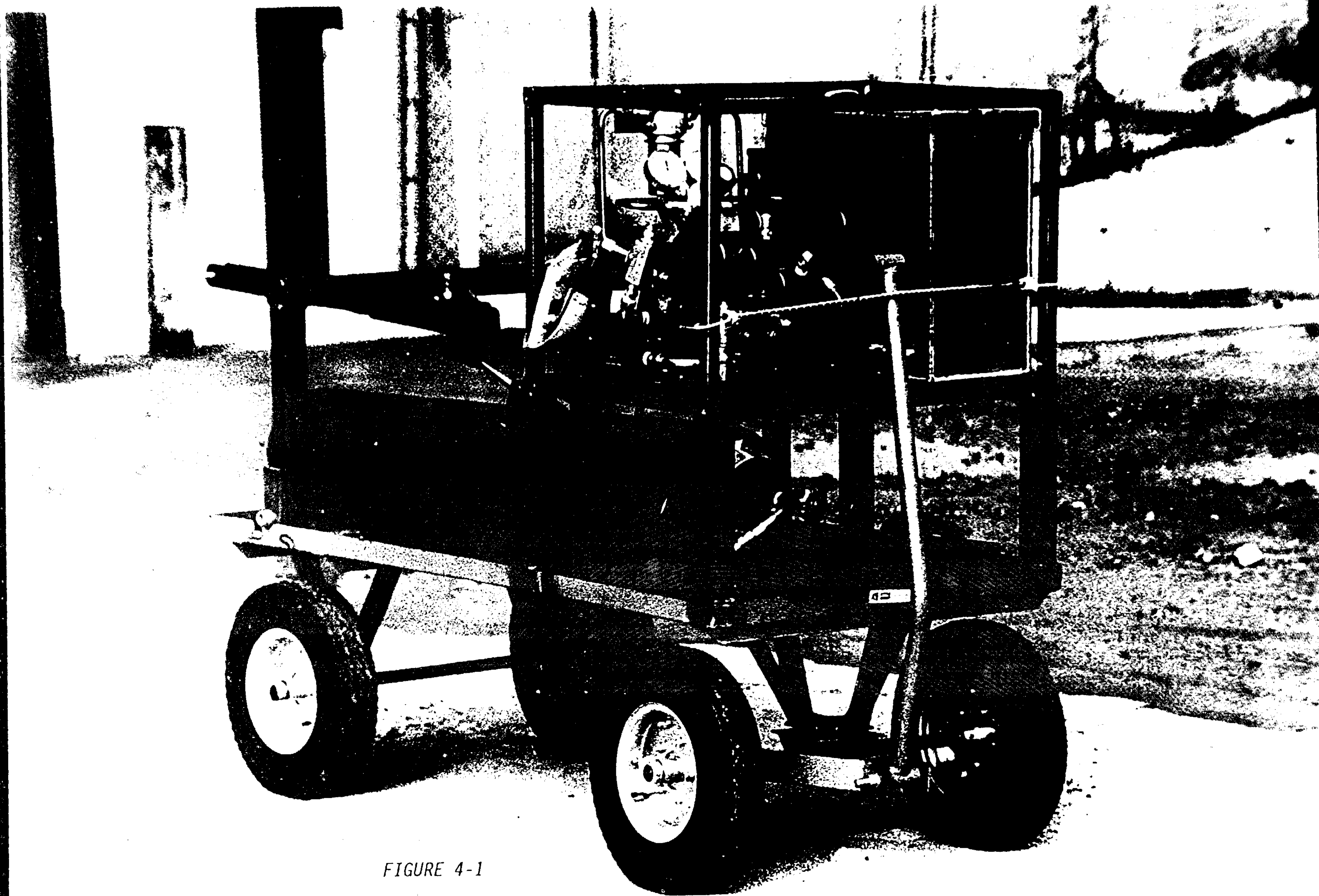


FIGURE 4-1

nitrogen gas. The center hose terminates in a spigot which is used to supply filtered oil under low pressure. The right hose is for high pressure nitrogen gas and includes a check valve to prevent gas from the suspension unit from having to fill the whole hose when a pressure check is made. In addition, a manually operated hand valve can be used to save the gas stored in the necessarily long supply hose while the hose termination is being moved from one site to another. The tee connection into the hose termination of this line connects a pressure transducer which, in conjunction with the appropriate conditioning equipment, is used to check high pressure gas level. Figure 4-3 shows the remainder of the pressure testing equipment which is contained in a steel storage box, normally stowed with the hoses on the charge cart. This box contains a battery operated strain gage transducer conditioner with integral read out and a separate charger for the conditioner battery. Also included is a cable to make the interconnection between conditioner and transducer.

The roadwheel jack supplied with the HSS equipped P-7 is simply a modification of a commercially available hydraulic jack assembly (Figure 4-4) with remote pump (Figure 4-5) facility. The hydraulic jack is adapted with a lower end fitting to allow it to stand on the vehicle track. The upper end is adapted to cradle the end of the suspension unit roadarm. A separate riser block is used to lift the roadwheel through the considerable height necessary to clear the track guides prior to application of the cylinder. The cylinder and pump are then used to raise the wheel slightly more and allow removal of the roadwheels. The cylinder generates sufficient thrust to easily overcome the suspension unit gas spring and roadwheel and hub assemblies can therefore readily be changed without discharging the suspension units.

4.2 PREPARING THE CHARGE CART FOR OPERATION

4.2.1 Place a charged tank of dry nitrogen on one of the rails provided on the bed surface of the charge cart. (A second

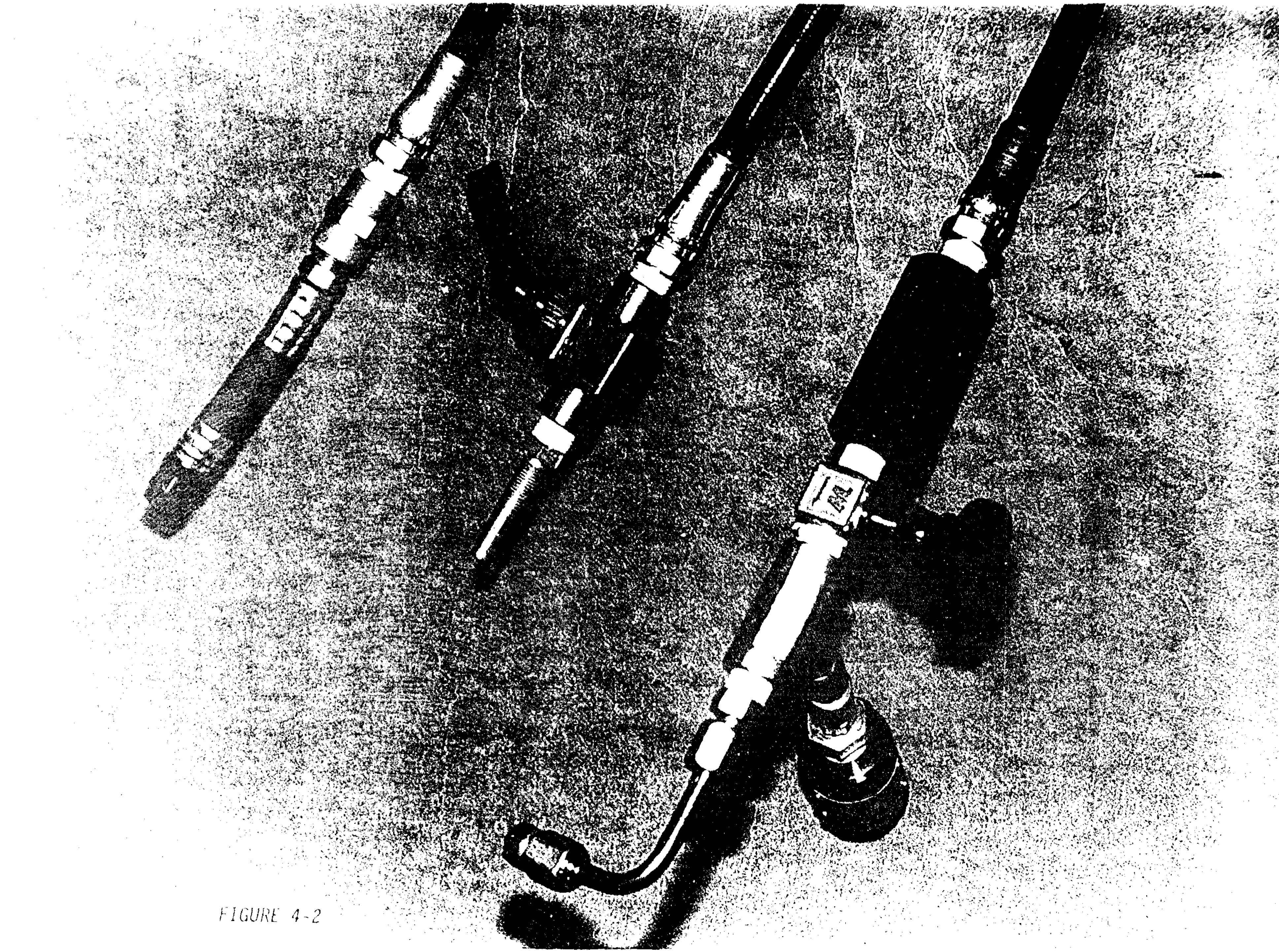


FIGURE 4-2

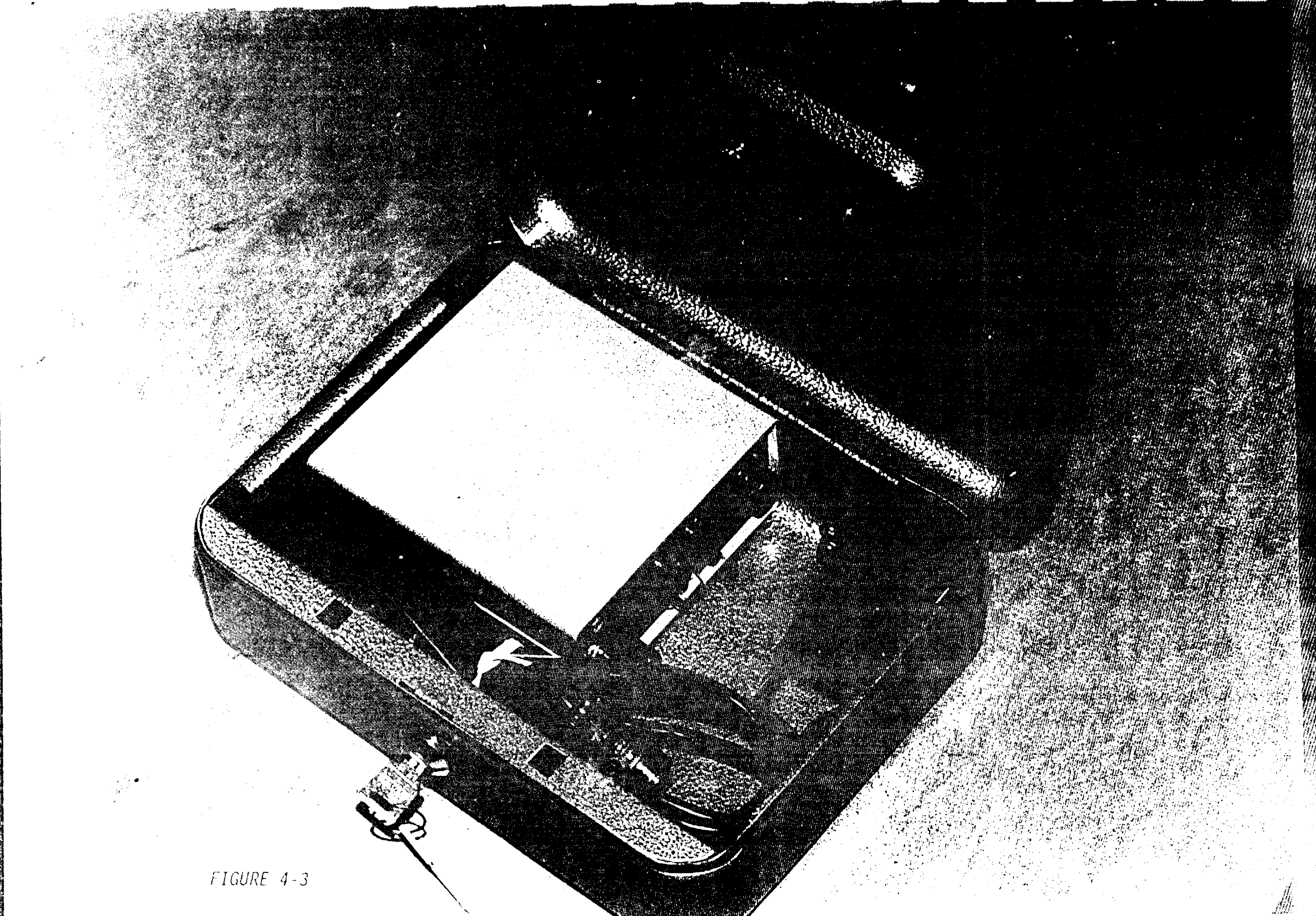


FIGURE 4-3

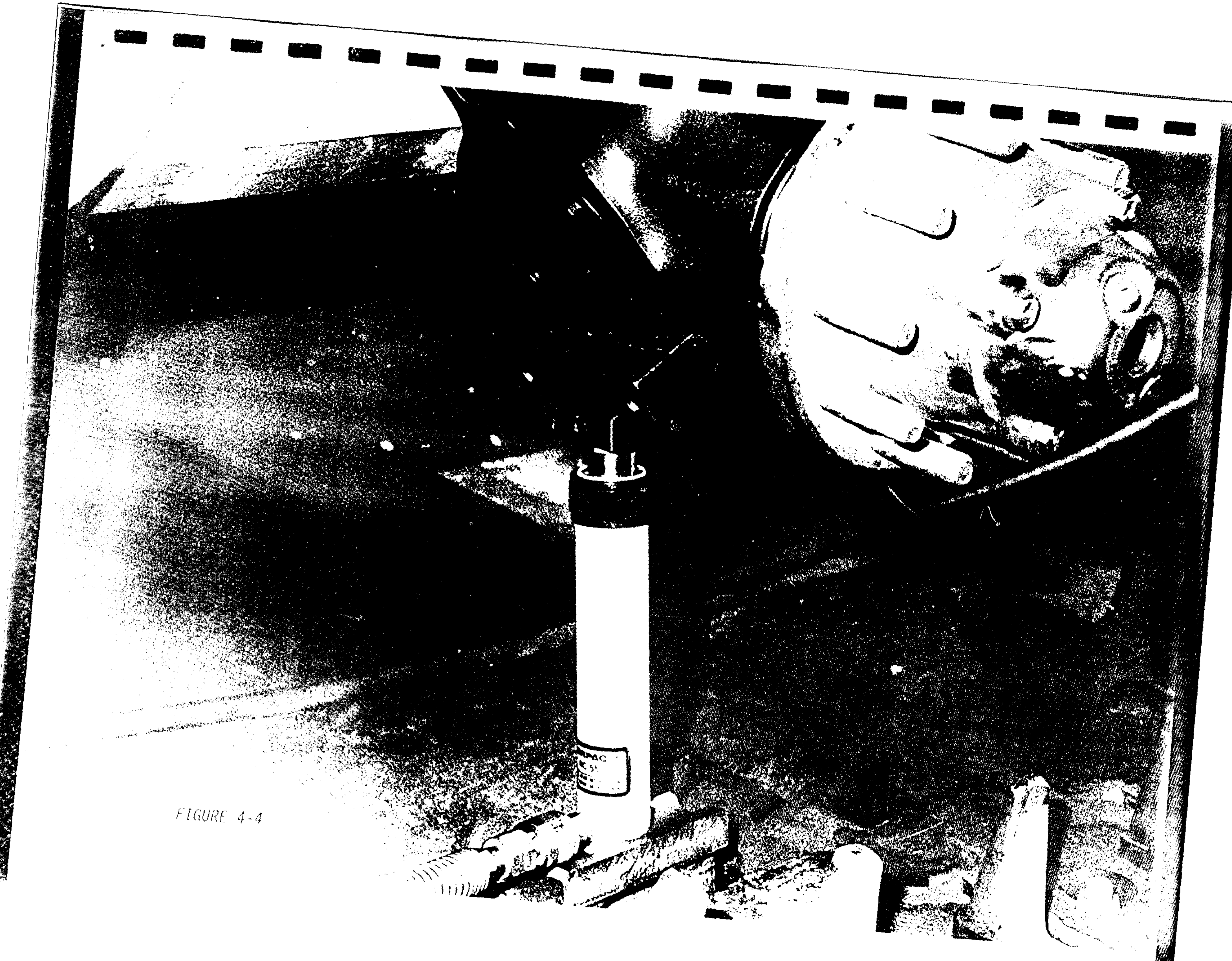


FIGURE 4-4

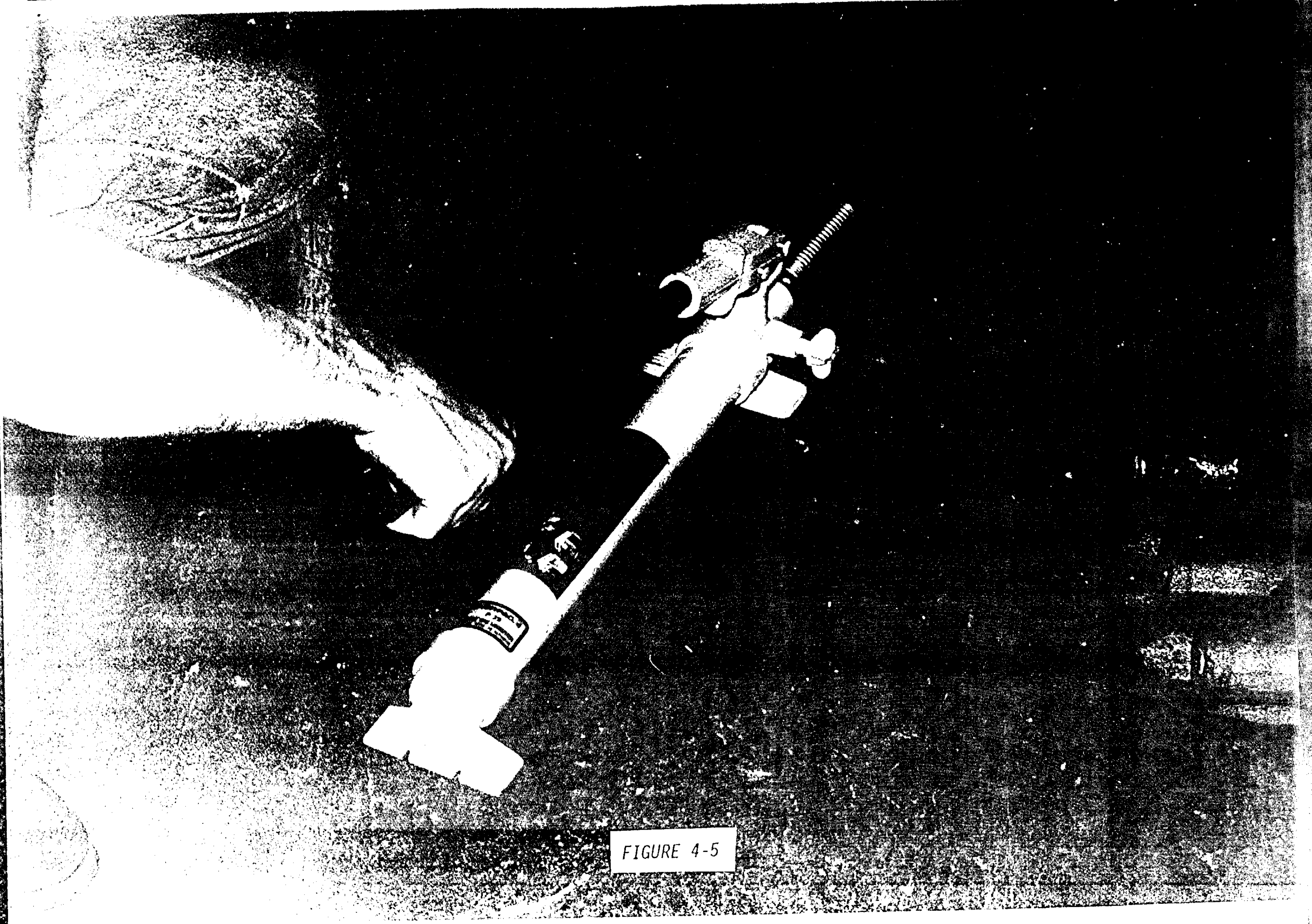


FIGURE 4-5

rail is provided to allow storage of an optional nitrogen tank for future use.)

4.2.2 Connect the flexible gas inlet hose to the nitrogen tank outlet fitting and fasten securely.

4.2.3 Open the nitrogen tank hand valve. The tank pressure will register on the right hand gauge of the regulator above the air booster.

4.2.4 Connect a shop air supply hose (nominal 100 psi) to the air intake fitting just to the left of the gas regulator. Make sure the hand operated needle valve associated with this fitting is closed before connecting the air supply.

4.2.5 Remove the pressure transducer conditioning amplifier and associated interconnecting cable from their storage box.

4.2.6 Make appropriate connections of the interconnecting cable at the rear of the conditioner box and at the pressure transducer situated at the end of the high pressure hose.

4.2.7 Check battery condition of the conditioner by turning the control knob on the front panel fully counter-clockwise to the BATTERY CHECK position. Turn the panel power switch ON. The meter reading should always be above 800 for proper operation of the system. (See equipment manual in appendix for charging instructions.) Typical reading at full battery charge will be something above 1200.

4.2.8 Rotate the control switch on the front panel of the conditioner clockwise to Channel 1. Make sure no pressure is seen at the pressure transducer by bleeding off any excess through the fitting at the end of the hose. The panel reading should now be "0". If not, adjust the zero potentiometer on the front of the panel until the meter does read "0".

4.2.9 Depress the CAL button located on the front of the instrument panel. The reading should now be 366 or 367. If this is not the case, adjust the span adjust for Channel 1 until it is.

4.2.10 Re-run steps 4.2.8 and 4.2.9 until the conditions specified in both steps are met without further adjustment.

4.2.11 Turn the pressure regulator control knob clockwise until the left hand gauge reads 60 psi.

The charge cart is now ready for operation.

5.1 CHECKING THE SPRING GAS CHARGE

Make sure that the vehicle is at the prescribed 17 inch ground clearance level. Use jack stands, if necessary, to control the height. Move the charging cart (prepared as indicated in Section 4.2 for operation) to within comfortable working proximity of the suspension unit to be checked. Then proceed through the following steps:

5.1.1 Refer to the section view of the suspension unit roadarm designated Figure 5-1. Carefully clean the area around the charging valve cover (1).

5.1.2 Remove two screws (2) and remove the charging valve cover from the roadarm.

5.1.3 Carefully clean the area surrounding the charge valve (3) and the bleed plug (4).

5.1.4 Remove the bleed plug from the roadarm and insert the straight thread end of the flared union (1/4" 37 deg. flare to 1/4" straight thread) provided. WARNING: Do <u>NOT</u> substitue brass or copper fittings in this high pressure application.

5.1.5 Connect the end fitting nut of the charge cart high pressure hose to the flared end of the union just installed in the roadarm.

5.1.6 Make sure the hand valve installed in the high pressure hose is closed (clockwise).

5.1.7 Open the charge valve (3) by turning it counter clockwise one-half turn.

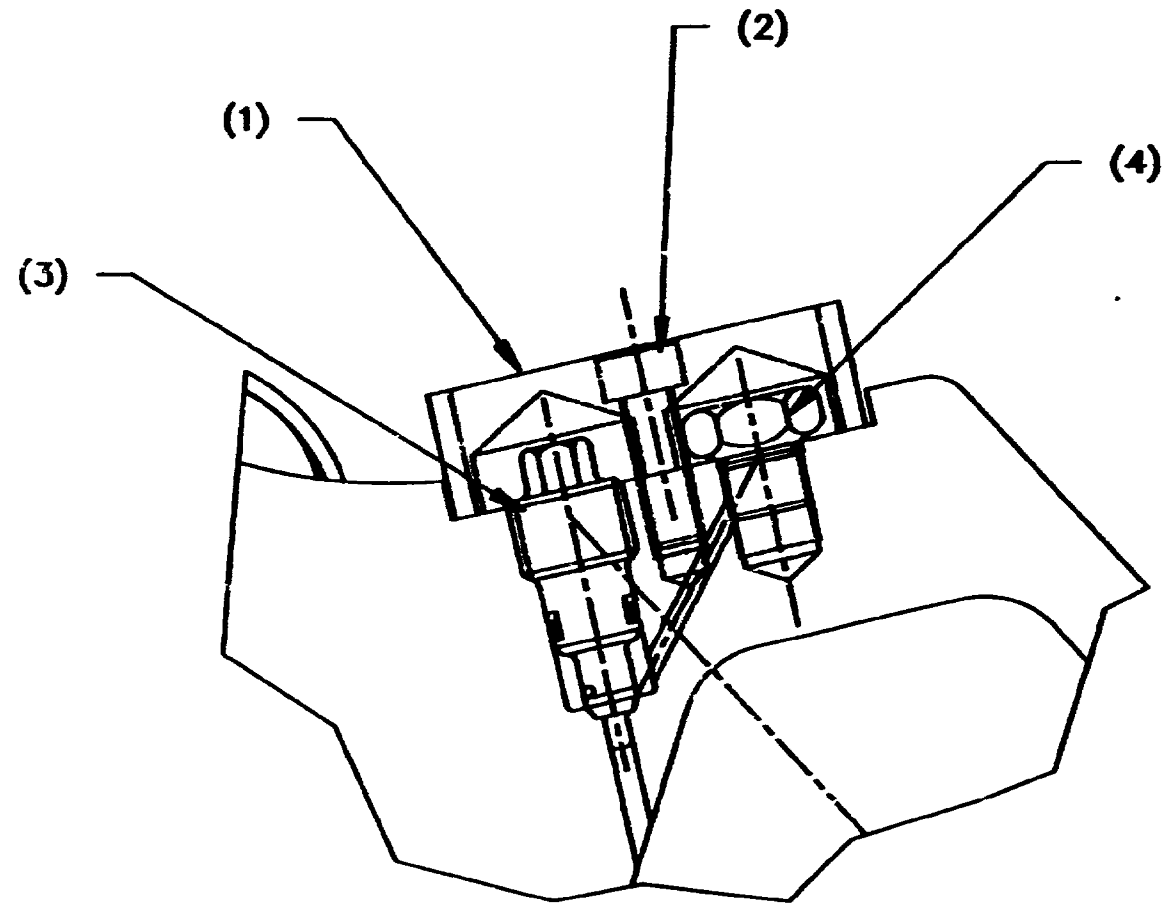


FIGURE 5-1

5.1.8 Observe the pressure now registered on the pressure transducer conditioning instrument. **NOTE:** The numerals shown will represent one-tenth of the actual pressure. For example, 2,560 psi will read as 256 on the instrument.

5.1.9 If the gas pressure needs to be modified, continue with step 5.1.10. If the pressure level is satisfactory, skip over to step 5.1.15.

5.1.10 Open the hand valve on the nitrogen bottle (turn counterclockwise) and observe the tank pressure as indicated at the right-hand pressure gage of the regulator.

5.1.11 If the pressure observed is higher than that required in the suspension unit, no boost will be required and control of the gas to be inserted into the unit will be accomplished by the small hand valve near the end of the high pressure hose. Open this valve (counterclockwise) slightly and gradually elevate the pressure in the suspension unit until the proper pressure is reached. Close the hand valve and continue to observe the pressure as it stabilizes. If it settles to a pressure lower than required, add more gas by opening the hand valve again. If stability occurs at an excessive pressure, bleed gas off by slightly loosening and then re-tightening the high pressure line to the flare union. The final pressure should be within 1% of target pressure and should be stable within 1/4% of target for a minimum observation period of 30 seconds. Achieving this goal will be a bit difficult for the operator at first, but will be accomplished relatively easily after some practice.

5.1.12 If a pressure higher than that existing in the nitrogen tank is needed at the suspension unit, boost will be required. In this event, open fully the hand valve at the end of the high pressure hose. A check valve in the line will prevent back flow from the suspension unit to the tank.

5.1.13 Gradually open the hand valve controlling the air line input to the booster. The booster will commence to "chug" and after a few cycles an increase in pressure at the transducer will be noted.

5.1.14 Continue operating the booster as required to bring the pressure to the final desired value. Use the technique described in 5.1.11 except that gas addition is controlled by the boost air line hand valve rather than the high pressure gas line hand valve. The same tolerances on pressure levels and stability apply.

5.1.15 Close the charging valve (3) by turning it clockwise till it seats. Tighten to 30 foot-pounds. Do not over-torque the charging valve as this can damage the critical seat.

5.1.16 Close the high pressure line hand valve to save the gas stored in the hose. (Bleed the hose off when the main tank valve is closed and the hose is stored after the working session.)

5.1.17 Slightly loosen the end fitting nut at the flare union to allow the gas trapped in the end of the high pressure line to bleed off. Then remove the nut and line from the flare union.

5.1.18 Remove the flare union from the roadarm and re-install the bleed plug (4).

5.1.19 Replace the charging valve cover (1) and install two screws (2).

NOTE: Cleanliness in the handling of parts during the checking of the spring gas charge cannot be too highly stressed. Introduction of any contaminate into the suspension unit can be a cause of catastrophic failure. The suspension unit is built to withstand a great deal of contamination and abuse on the outside, but the interior must be kept clean to assure proper performance.

5.2 CHECKING CRANK CASE FLUID LEVEL

5.2.1 Refer to Figure 5-2. Clean the area around the crank case fill assembly (1) carefully.

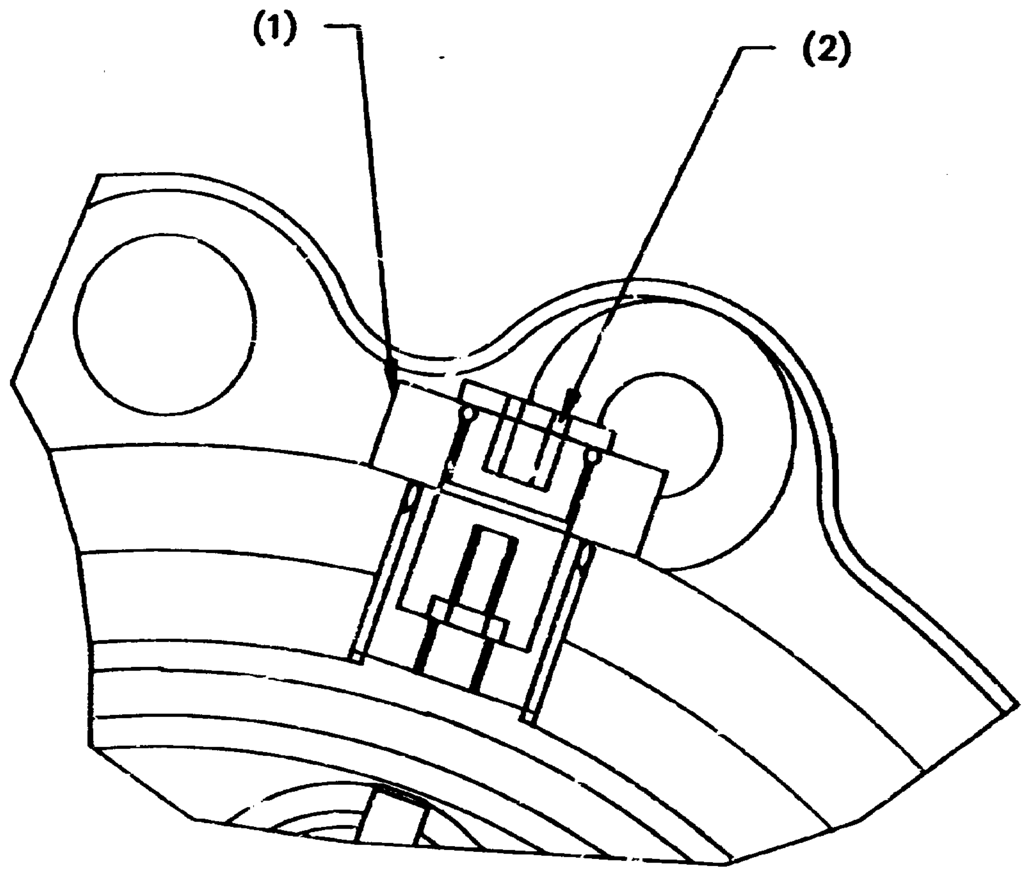


FIGURE 5–2

5.2.2. Remove plug (2) from the assembly.

5.2.3 Using a suitable tool, depress the valve stem of the fill valve assembly and allow the gas charge to escape. Make sure to hold the valve open long enough to allow thorough bleeding of the gas charge.

5.2.4 Refer to Figure 5-3. Carefully clean the area around the crank case blow off valve assembly (1).

5.2.5 Remove the crank case blow off valve assembly from the torque cover.

5.2.6 Visually inspect for fluid level, using an auxiliary light source if necessary. Fluid level should be approximately at the lower edge of the blow off valve port and, in consequence, fluid should slowly run out when the assembly has been removed. NOTE: No significant change to the crank case oil level should normally occur in regular service. It should therefore be unnecessary to add oil to or remove oil from the crank case except during repair and overhaul operations. Any major change in the oil level found during this check should therefore, be considered a cause for concern and the reasons should be investigated.

5.2.7 If the crankcase fluid level is <u>not</u> as specified, and the decision is made to correct it, proceed with step 5.2.8. Otherwise, skip to step 5.2.9.

5.2.8 Should the crankcase oil level be too high, it can be reduced simply by allowing the excess to run out the blow off assembly port. When complete, proceed to step 5.2.9. If the level is low, remove the entire crankcase fill assembly (Item (1) in Figure 5.2). Bring the charging cart (prepared for operation per steps 4.2.1, 4.2.2, 4.2.3 and 4.2.11) near to the suspension unit. Use the filtered oil hoso (termination is a spigot) and add oil as roquired through the opening left by the crankcase fill assembly. When complete, re-install the crankcase fill assembly into the roadarm.

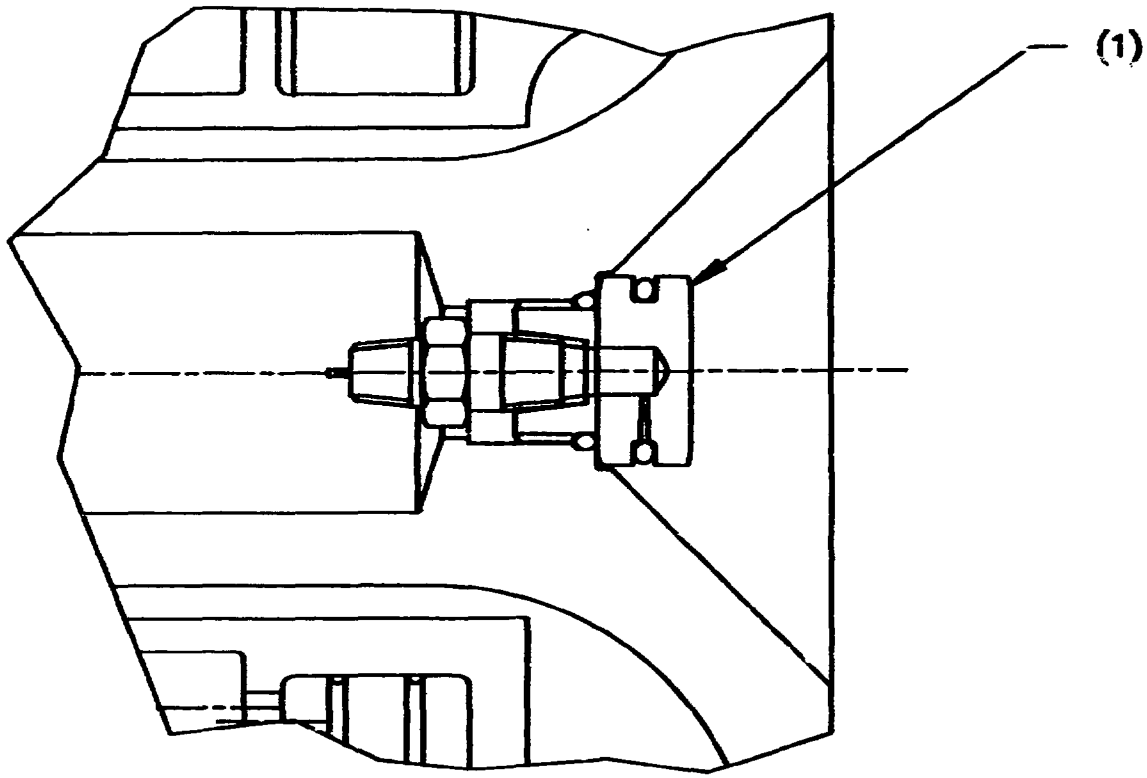


FIGURE 5–3

5.2.9 Re-install the crankcase blow-off valve into the torque cover.

5.2.10 Re-install the cover plug into the crankcase fill assembly.

5.3 CHECKING THE CRANK CASE GAS CHARGE

5.3.1 Refer to the section view of the suspension unit roadarm labelled Figure 5-2. Carefully clean the area around the crank case fill assembly (1).

5.3.2 Remove the plug (2) from the crank case fill adaptor.

5.3.3 Bring the charging cart (prepared for operation per steps 4.2.1, 4.2.2, 4.2.3 and 4.2.11) near to the suspension unit to be tested.

5.3.4 Apply the low pressure hose end fitting to the air inlet valve of the crank case. Hold the hose in position long enough to allow the pressure to stabilize to within 1 psi of the regulated value observed (set to 60 psi in the preparation stage) when the hose end fitting is free standing.

5.3.5 Remove the hose from the air inlet valve.

5.3.6 Re-install plug (2) into the crankcase fill adaptor.

6.1 REMOVING/REPLACING ROADWHEEL(S)

Because of physical considerations the roadarm jack used with the standard P-7 torsion bar suspension system is not applicable to the new hydropneumatic suspension units. This being the case, CGT has supplied with the vehicle a suitable roadwheel jack which utilizes hydraulics for its operation. The roadwheel jack package consists of:

- A manually operated hand-pump.
- A lift cylinder with end fitting adaptation.
- A roadwheel riser block

To remove a roadwheel set:

6.1.1 Place the riser block on the track in front of (or behind, in the case of station number 1) the roadwheel set to be removed. Utilize that portion of the track outboard of the track guides and make sure the two cleats on the riser engage the rectangular openings in adjacent track blocks. This will assure that the riser does not slip in the succeeding operation.

6.1.2 Drive the vehicle forward (or back, if the riser has been placed behind the wheel set) to cause the wheel set to climb to a central position on top of the riser. The lift of the wheel set will amount to approximately 4 1/2 inches.

6.1.3 Slightly loosen the ten (10) restraining nuts on the wheel set while the set is prevented from rotation by the riser block.

6.1.4 Place the roadwheel jack cylinder in position behind the roadwheel set. The lower end of the cylinder will engage two successive rectangular openings in the track. The upper end will cradle the lower corner of the suspension unit roadarm. (See Figure 4-4).

6.1.5 Close the hand valve of the roadwheel jack pump. Pump the handle until the cylinder has raised the wheels approximately 1/2 inch above the riser block.

6.1.6 Remove the ten (10) retaining nuts and washers from the wheel set completely. Remove each wheel in turn.

6.1.7 Install the replacement wheels by sliding them in turn over the threaded studs of the hub assembly.

6.1.8 Place a washer and nut on each of the ten (10) threaded studs. Snug the nuts down to bring the wheels into their proper position.

6.1.9 Open the hand valve of the roadwheel jack pump and allow the wheels to drop and re-engage the riser block.

6.1.10 Torque ten (10) roadwheel nuts to 160 foot pounds.

6.1.11 Remove the roadwheel jack cylinder from it's position under the roadarm.

6.1.12 Move the vehicle sufficiently to clear the riser block and remove it from the track.

NOTE: For servicing, repair and overhaul of the roadwheel hub assembly, see Figure 6-1. Oil level should be checked weekly, or at any indication of leakage as evidenced by dampness on the exterior surfaces of the assembly.

6.2 REMOVING/REPLACING SUSPENSION UNIT

6.2.1 Remove roadwheel set from suspension unit as described in 6.1.1 through 6.1.6.

6.2.2 Refer to Figure 5-1. Carefully clean the area around the high pressure charging valve cover (1).

6.2.3 Remove two cover mounting screws (2) and the charging valve cover from the roadarm.

6.2.4 Carefully clean the area surrounding the charge valve (3) and bleed plug (4).

6.2.5 Remove bleed plug from the roadarm.

6.2.6 Open charge valve a slight amount until gas starts to flow. Note that it is necessary to allow the gas to escape very gradually to avoid the loss of oil as well.

6.2.7 Refer to Figure 5-2. Carefully clean the area around the crankcase fill assembly (1) and remove plug (2). (The crankcase gas charge should be bled off per 5.2.3 if further work is to be done on suspension unit but need not be done simply to allow removal of the unit from its mounting).

6.2.8 Screw the lifting eye supplied with the charging cart into the opening made by removal of the plug from the crank case fill

NOTES:

1. INSTALL NUT-10888118 AS FOLLOWS:
   A. APPLY 100-110 FT LBS TORQUE WHILE ROTATING WHEEL
   B. BACK OFF NUT UNTIL THERE IS NO TORQUE
   C. APPLY 70-75 FT LBS TORQUE WHILE ROTATING WHEEL
   D. BACK OFF NUT TO FIRST COTTER PIN HOLE. IF TRAVEL TO FIRST HOLE IS LESS THAN 15 DEGREES BACK OFF NUT TO NEXT HOLE
2. SEAL AND SEAL MOUNTING SURFACES SHALL BE FREE OF LUBRICANT AT ASSEMBLY
3. BEARING CUPS AND CONES SHALL BE FROM THE SAME MANUFACTURER AND SHALL BE REPLACED AS AN ASSEMBLY
4. INSTALLATION TORQUE 22-24 FT LBS
5. FILL WITH LUBRICANT, GRADE 15W-40. SPEC MIL-L-2104 SO THAT WITH HUB IN HORIZONTAL POSITION AND ONE FILL HOLE ON TOP, OIL SHOULD COVER SIGHT GLASS, BUT SHOULD NOT BE ABOVE TOP FILL HOLE.
6. INSTALLATION TORQUE 181-188 FT LBS

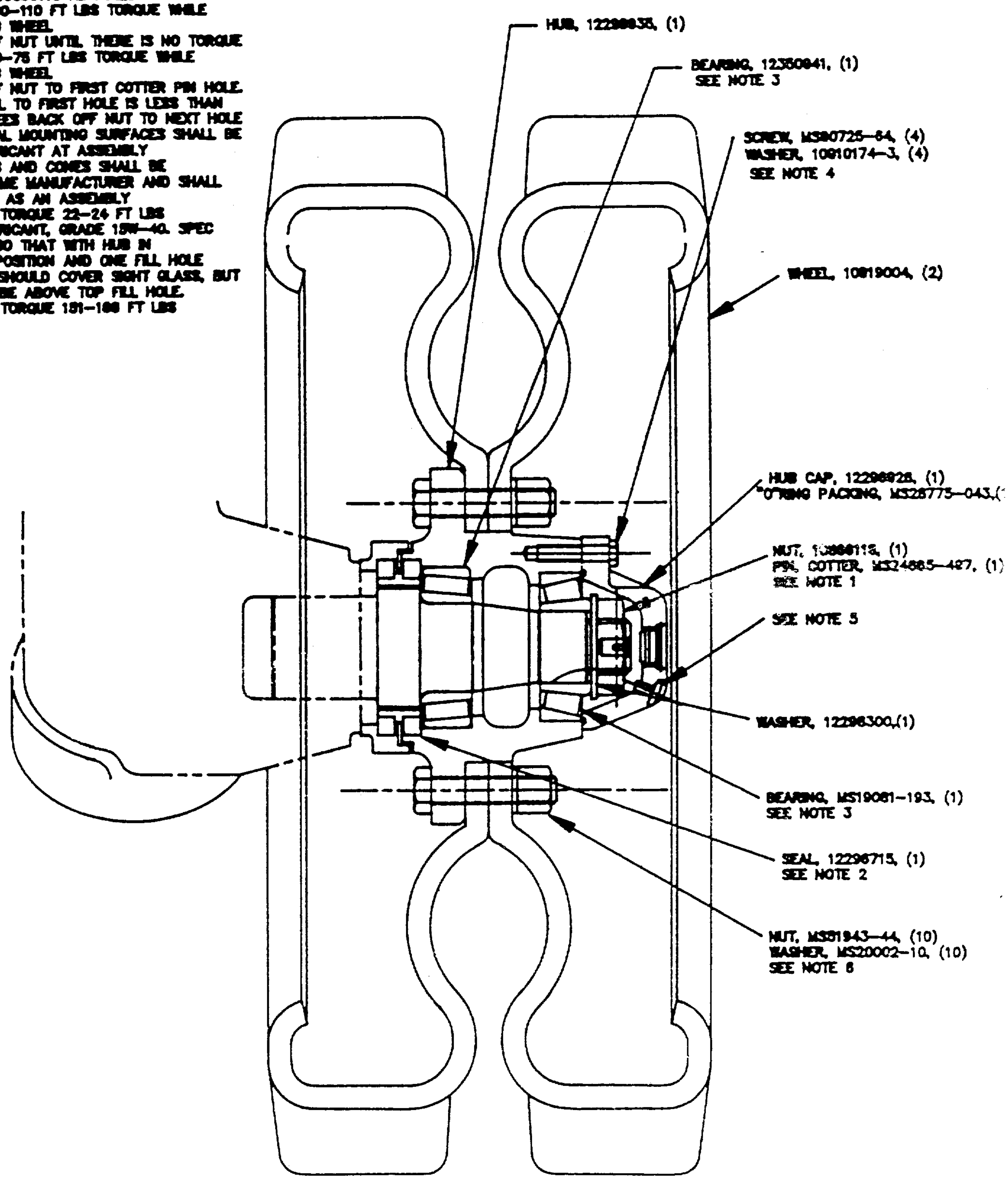


FIGURE 6-1

valve. Leave the eye 1/2 turn loose from bottoming to allow it to be used as a swivel.

6.2.9 Remove nine (9) 5/8-11 bolts fastening the suspension unit to the vehicle hull. Note that it will be necessary to move the roadarm angularly in order to achieve access to two of the hold down bolts. This can be accomplished after completion of the gas spring bleed process by using a track bar to move the roadarm up and down as required.

6.2.10 Remove the shoulder bolt from the end of the boom on the charging cart and move the cart into position so that the slot at the end of the boom straddles the eye threaded into the crank case fill adaptor.

6.2.11 Replace the shoulder bolt through the end of the lifting boom so that it passes through the boom and eye at the same time.

6.2.12 Close the valve on the lift cylinder hand pump and apply action to the pump handle to cause the lifting cylinder to support most of the weight of the suspension unit.

6.2.13 Rock the suspension back and forth while gradually applying outboard effort on the charging cart and in turn, the lifting boom. The suspension unit will come free of the hull and be suspended in air, held by the boom. Lower the lifting boom to allow the suspension unit to rest on the floor or other surface and remove the shoulder bolt from the lifting eye.

6.2.14 To replace a suspension unit on the hull, clean the mounting surfaces and pilot diameters of the suspension unit and mounting ring, making sure to remove any cured sealant left from the previous installation. Coat liberally with two part sealant per MIL-S-81733 Type II.

6.2.15 Repeat steps 6.2.7, 6.2.8, 6.2.10, and 6.2.11 to prepare the replacement unit for installation on the hull.

6.2.16 Close the valve on the lift cylinder hand pump and operate the pump handle to lift the suspension unit into the approximate position for installation on the hull.

6.2.17 Move the charging cart into position and spot the suspension unit so that it "hangs" from the torque pin extending from the mounting ring. Rock the suspension unit back and forth to cause it to engage the pilot diameter and drop into position on the mounting ring.

6.2.18 Install nine (9) 5/8-11 bolts doped with the sealant described in 6.2.14 to fasten the suspension unit to the vehicle hull. Note that rotation of the roadarm by the use of a track bar will be necessary to gain access to two of mounting bolts.

6.2.19 Disconnect the lifting boom from the suspension unit. Tighten nine (9) mounting bolts to 150 foot pound level.

6.2.20 Re-charge the gas spring, re-check crankcase fluid level, and replace gas charge in the crankcase per sections 5.1, 5.2, and 5.3.

6.3 REMOVING/REPLACING TRACK SUPPORT ROLLER

6.3.1 Clear the area of the track roller of mud and debris as necessary.

6.3.2 Using suitable means, jack the track up from the track roller slightly in order to relieve the load on the roller assembly.

6.3.3 Remove five (5) 5/8-11 bolts holding the track roller to the hull. The bolts are accessible using a socket wrench passed through holes in the roller hub.

6.3.4. Remove the track roller assembly from the hull.

6.3.5 To replace a track roller assembly on the hull, clean the mounting surface at the rear of the assembly and coat liberally with sealant per MIL-S-18733 Type II. If necessary, clear the area of mounting on the hull of hardened sealant left from the previous installation.

6.3.6 Position the track roller assembly at the hull bolt pattern and insert five (5) 5/8-11 mounting bolts which have been doped with the sealant described in 6.3.5.

6.3.7 Torque the five (5) mounting bolts to 150 foot pounds.

6.3.8 Remove the track jacking provisions from the vehicle.

NOTE: For servicing, repair and overhaul of the track roller assembly, see Figure 6-2. The assembly is very similar to that used on an M2 vehicle, but has been modified to reduce the height of the hubcap to allow clearance with respect to the track guides of the vehicle. Oil level should be checked weekly, or at any indication of leakage as evidenced by dampness on the exterior surfaces of the assembly.

7.1 CHECKING THE TRACK TENSION

In addition to track roller assemblies, a slide plate has been added to each side of the vehicle at Station 3. This slide plate serves the purpose of minimizing track droop and possible resulting damage to the suspension units. At the same time, it serves as a convenient method of checking track tension by indicating the amount of catenary droop between the track rollers located at Stations 1 and 5. To check track tension:

7.1.1 Allow the vehicle to come to a free rolling stop on relatively level, hard ground.

7.1.2 Check the spacing between skid plate and track on each side of the vehicle. Proper clearance should be approximately 1/2 inch, which corresponds to a track tension of 6,000 pounds.

7.1.3 Apply high pressure grease as required in the usual fashion to the tensioner at the rear of the vehicle to bring the track to the appropriate 1/2 inch clearance.

NOTES:
1. SEAL AND SEAL MOUNTING SURFACE SHALL BE FREE OF LUBRICANT AT ASSEMBLY
2. BEARING CUPS AND CONES SHALL BE FROM THE SAME MANUFACTURER AND SHALL BE REPLACED AS AN ASSEMBLY
3. INSTALL NUT AS FOLLOWS:
   A. TIGHTEN NUT TO 40–50 FT LB TORQUE WHILE ROTATING WHEEL SLOWLY
   B. BACK OFF NUT TO ZERO TORQUE
   C. TIGHTEN NUT TO 8–10 FT LB TORQUE WHILE ROTATING WHEEL SLOWLY
   D. BACK OFF NUT TO NEXT COTTER PIN HOLE BUT DO NOT EXCEED 30° ROTATION
4. INSTALLATION TORQUE 22–24 FT LB
5. FILL WITH LUBRICANT GRADE 15W–40 SPEC MIL–L–2104 SO THAT WITH SPINDLE IN HORIZONTAL POSITION AND FILL HOLE AT 45° ABOVE HORIZONTAL, OIL SHOULD BE NO HIGHER THAN LIP OF FILL HOLE AND NO LOWER THAN BOTTOM EDGE OF FILL HOLE

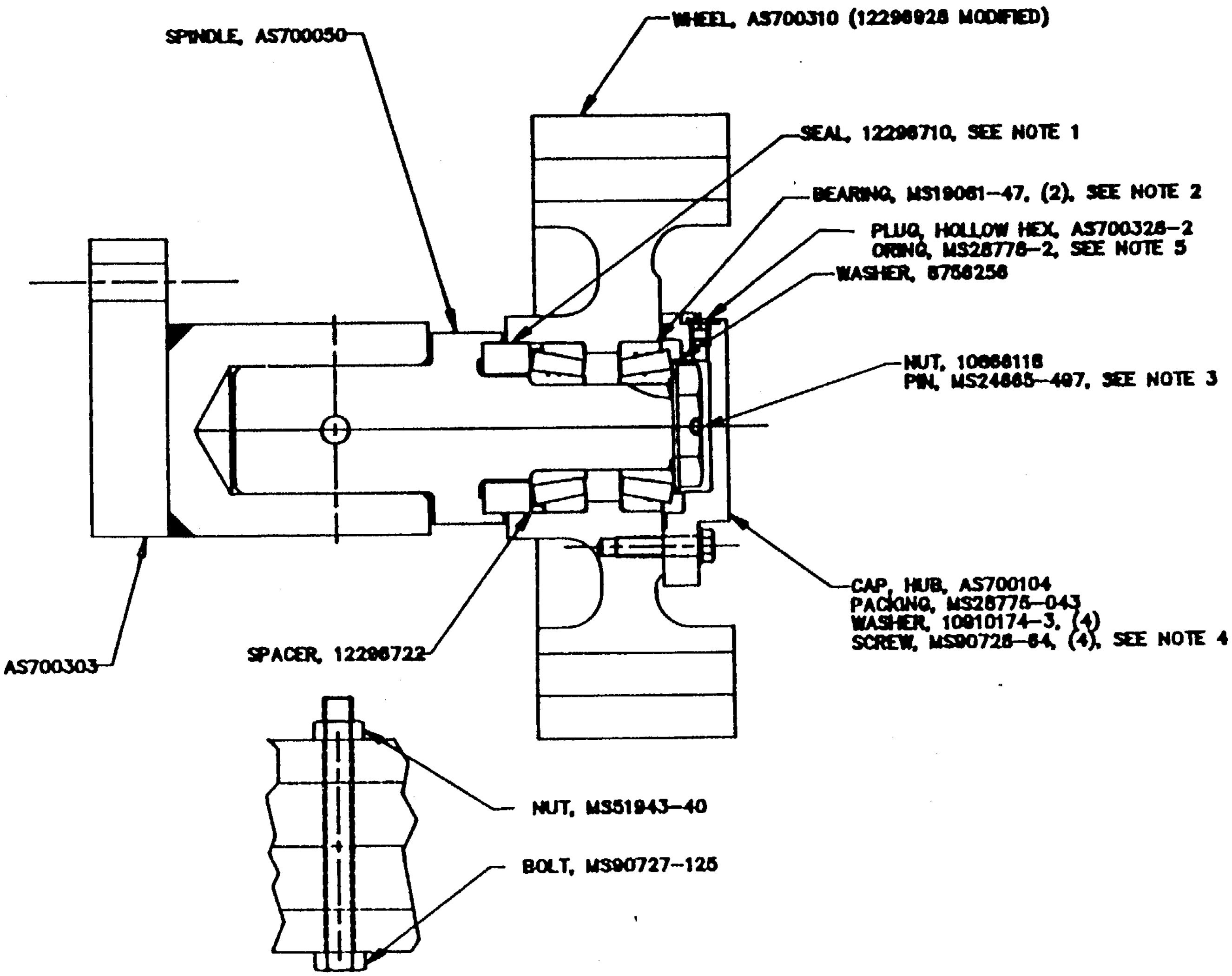


FIGURE 6–2

APPENDIX

INSTRUCTION MANUAL

FOR MODEL 210

INDICATOR

GSE INC. A Subsidiary of Core Industries

23940 Research Drive • Farmington Hills, MI 48024-1090 U.S.A.

(313) 476-7875 • Telex: 23-0738

T-13878-A
10/24/86

1.0 INTRODUCTION TO THE MODEL 210

The GSE Model 210 Indicator is a portable, lightweight instrument designed to monitor signals from strain-gage transducers. The Model 210 is specifically designed for use with the GSE Model 768 Belt Tension Sensor. This portable and versatile system is used primarily to test automotive V-Belt tension. The indicator can be calibrated for up to six (6) different V-Belt sizes using a selector switch with associated span potentiometers.

The Model 210 Indicator also features an internal selectable decimal point, a rechargeable battery, binding posts for external calibration resistors, an MS connector, a battery recharge jack and an analog output jack. The following controls are used on the Model 210:

1. A **POWER SWITCH** turns the instrument ON and OFF (the battery may be charged with the switch in either position).

2. A **CALIBRATION BUTTON** shunts the calibration resistor (mounted in the binding posts in rear) across the +power and +signal leads to simulate a load. This simulated load is then used to span the instrument, matching it to the transducer.

3. The **SPAN SELECT SWITCH** is used to select the desired calibration setting. It also selects the Battery Check function.

4. The **SPAN ADJUST** potentiometers scale the instrument during calibration.

5. The **ZERO** potentiometer allows the operator to tare out any zero offset.

6. The **DECIMAL POINT** selector switch bank is located inside the instrument and may be accessed by removing the screws from the bottom cover and opening the case.

****

2.0 SET UP AND CALIBRATION

1. Connect the transducer to the input connector. If the transducer connector must be wired, use the following wiring code:

PIN DESIGNATION	FUNCTION
A	+ EXCITATION
B	- EXCITATION
C	+ SIGNAL
D	- SIGNAL
E	SHIELD

2. Check the battery by selecting the Battery Check function with the Span Select switch. In the Battery Check position the display will indicate the condition of the battery. A reading of 800 counts or less indicates a LOW BATTERY charge level. To avoid damage, the battery should be charged for 14 HRS. before further use. Leaving the instrument plugged in, with the power switch either ON or OFF, will recharge the battery. If the instrument is stored for any length of time, the battery level must be checked before use.

3. If desired, change the decimal point position by using the internal "dip switch" bank. The switches place the decimal point as follows:

   #1: 0000.
   #2: 000.0
   #3: 00.00
   #4: is spare

4. Select a channel with the span select switch.

5. Adjust the Zero pot (with no load on the transducer) until the display reads zero.

7. Install the Calibration Resistor provided with the transducer in the binding posts on the rear of the instrument.

8. Depress the Cal Button located on the front of the instrument.

9. Using the span pot for the selected channel, adjust the display to match the calibration value stamped on the cal resistor label.

10. Recheck the Zero and Span and re-adjust as needed.

NOTE: The battery condition should be checked every two (2) hours when the instrument is in use in the battery mode. A nine (9) volt alkaline battery may be substituted if the rechargeable battery should fail. **DO NOT ATTEMPT TO RECHARGE AN ALKALINE BATTERY!**

****

3.0 OPTIONAL CAL METHOD

This method uses pre-tensioned V-Belts set up under laboratory conditions to precise load levels and is recommended only for those who desire the best possible accuracy. Up to six different V-Belts may be loaded with dead weights and the Model 210 indicator is then used to calibrate the transducer on the master test fixture.

1. Turn the instrument on and connect the V-Belt sensor.

2. Check the battery condition and recharge if necessary.

3.0 OPTIONAL CAL METHOD cont'd

2. Check the battery condition and recharge if necessary.

3. Adjust the Zero pot to read zero.

4. Clamp the sensor onto the pre-tensioned V-Belt.

5. Select the "CHANNEL 1" Span pot and adjust the Model 210 to match the load applied to the V-Belt.

6. Move the channel selector switch to the next position and repeat steps 1 thru 5 for the next belt size that will be used. Repeat this procedure for each belt that will be used.

****

SPECIFICATIONS FOR MODEL 210 INDICATOR

NON-LINEARITY .... ± 0.25% FS

BATTERY .... Rechargeable 9 volt, eight (8) hours plus of continuous use

RECHARGER .... 115/230 VAC, 50-60 Hz, input 12 VDC, 14 hours recharge time

BRIDGE EXCITATION ..... 2.5 volts DC, 350-1000 Ohm, Full Bridge

INPUT SIGNAL .... 0.4 - 5.0 mV/V for FS

ANALOG OUTPUT .... 1 volt DC nominal FS

DISPLAY .... 3 1/2 digit LCD, 1/2" high

CALIBRATION .... Six, switch selectable calibration settings

SHUNT CALIBRATION ..... Binding posts on rear panel for shunt calibration resistor

MAXIMUM READING .... 1999, track only

CONNECTOR MS-3102A-14S-5S

SIZE .... 5" W X 2.25" H X 5.25" D

WEIGHT .... 1 LB 2 Oz.

****

REPLACEMENT NICAD BATTERIES AND CHARGERS

Replacement TR 7/8 Varta NiCd 9V batteries
are available from GSE
by ordering part #12-10-2200.

Replacement N30-85/60B065 D & B Power Chargers
are also available from GSE
by ordering part #12-10-15827.

APPENDIX B

SPECIAL TOOLS

List and Description of Special Tools

Name	Description
Wrench, Relief Valve	Special spanner wrench to torque relief valve sleeve into roadarm spindle
Locator, Pump	Locate pump at collapsed position during roadarm installation
Clamps, Bearing	Clamp outer main bearing to roadarm during piston installation
Puller, Connecting Bar Pin	Installation and removal tool for connecting bar pin
Roller, Sleeve	Installation and removal tool for roadarm piston sleeve
Puller, Front Cover	Tool to allow quick removal of front cover
Wrench, Charging	Special wrench with multiple sizes to allow gas spring maintenance with one (1) wrench
Dummy Relief Valve	Modified relief valve body that allows pressure testing of damper hydraulic circuit
Roll Pin Installation Tool	Tool to install connecting bar roll pin
Damper Spring Compression Tool	Threaded rods used to compress damper piston springs

APPENDIX C

ACCEPTANCE TEST PROCEDURE

ACCEPTANCE TEST PROCEDURE
IN-ARM SUSPENSION UNIT
DTRC CONTRACT NO. N00167-88-C-0024 TO
CADILLAC GAGE TEXTRON, INC.
(CDRL A003)

CONFIGURATION PER NAVSEA DRAWING NO. 6599761

REVISION DATE:________________

Approval (Eng.)____________________ **(CGT)**

Date:__________________________

Drawing No. 6599850

REVISION STATUS

Revision	Description	Date

Sheet:																
Rev:																
Sheet:	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Rev:	_	_	_	_	_	_	_	_	_	_	_	_	_	_	_	_
Sheet:	17	18	19	20	21	22	23	24								
Rev:	_	_	_	_	_	_	_	_								

Drawing No. 6599850

1.0 Scope

This document establishes the test method and test equipment to be used in evaluating the functional performance of In-Arm Suspension Units (ISU) M/N 6599761-1-F, 6599761-1-R, 6599761-2-F, and 6599761-2-R. The -1 units are configured for the left (port) side and the -2 units for the right (starboard) side of the vehicle. -F units are trimmed for station 1 and 2 application and -R units are prepared for use on stations 3 through 6.

2.0 General Information

2.1 The ISU Assembly and its component parts shall conform as applicable to the detailed test parameters of paragraphs 5.1, 5.2, 5.3, 5.4, 5.5, and 5.6.

2.2 The working hydraulic fluid used in the ISU Assembly spring and crankcase sections shall be Mobil 423 and shall, prior to being put into service in the ISU, be passed through a fluid filter rated at 10 micron absolute or better.

2.3 All functional tests shall be performed at an ambient and ISU temperature of 80 +10'F unless otherwise specified.

3.0 Test Equipment

3.1 The test apparatus utilized for this procedure shall, at a minimum, incorporate the following features:

3.1.1 A structural assembly arranged to support the ISU in its normal operational attitude and using mounting provisions and fasteners closely simulating the vehicle installation. The structure shall be configured to allow installation of either a left (6599761-1) or right hand (6599761-2) ISU with a minimum of change over.

3.1.2 A means, such as a servo controlled hydraulic cylinder, of producing the motion and simulating the forces seen at the ISU wheel spindle when operating on a vehicle. This drive means shall provide sufficient stroke, at a minimum, to operate the roadarm through wheel spindle positions on demand from -5.0 inches to +12.0 inches (normal or "static" operating position is at 0.0 inches where the wheel spindle centerline is 9.38 inches below the rotational centerline of the roadarm). It shall, at a minimum, be adequately powered to provide vertical force levels at the spindle up to 40,000 pounds on a static basis and to 25,000 pounds dynamically while operating at a sinusoidal frequency of 0.3 Hz at the stroke amplitude indicated above. The drive shall be capable of operating at frequencies up to 5.0 Hz with proportionately reduced amplitudes.

3.1.3 Provisions to measure, on a bi-directional and continuous basis, the force applied by the drive of 3.1.2 to the ISU wheel spindle. The resulting measurement shall be accurate to within 100 pounds at all load values.

3.1.4 Means to continuously measure the vertical position of the ISU wheel spindle as it is operated by the drive of 3.1.2. The measurement shall be accurate to within 0.05 inches at all positions.

3.1.5 Provisions to continuously monitor the pressure existing in the ISU spring chamber during operation. Pressure will range from approximately 1,000 to 12,000 psig dynamically and will range from 18,000 psig for proof test purposes. The pressure measurement shall be accurate to within ±13 psi for all readings up to 5,000 psig, ±25 psi for all readings up to 10,000 psig and ±50 psi for proof pressure readings.

3.1.6 Measurement means to continuously monitor temperature at a selected external surface location on the test ISU. The equipment must be capable of covering a minimum range from +50 to +250°F. The temperature measured shall be accurate to within 2°F at all readings.

3.1.7 The necessary equipment to continuously and simultaneously record the data produced by the instrumentation devices described in 3.1.3 through 3.1.6 as the ISU is put through the test cycle.

3.1.8 The means to operate the test drive on a continuous and repeatable basis to simulate a typical cycle of input load and velocity conditions that the ISU might experience in severe vehicle operation. An actual recording of wheel versus hull position during a strenuous vehicle run used to drive the servo cylinder of 3.1.2 is one satisfactory method of arriving at this cycle simulator.

4.0 **Assembly**

All parts shall be carefully deburred and cleaned prior to assembly. Assembly shall be performed in a clean environment.

5.0 **Test Procedures**

5.1 **Damper Relief Valve**

5.1.1 Assembly Damper Relief Valve per 6599762, Sheet 2, and install in test fixture 6599854. Make connections per Figure I and follow procedure of 5.1.2 through 5.1.8.

5.1.2 Open shutoff valve (6).

5.1.3 Adjust pressure regulator (4) to increase the pressure seen at the gauge (3) from 1,000 psig at a rate not to exceed 100 psi per second. Continue increasing pressure until the reading at flow meter (2) reaches 2.0 gpm. Pressure at this condition shall be 3,000 to 3,200 psig. If lower, add shims to Relief Valve spring cartridge and, if higher, remove shims from the cartridge to bring the pressure into the specified range.

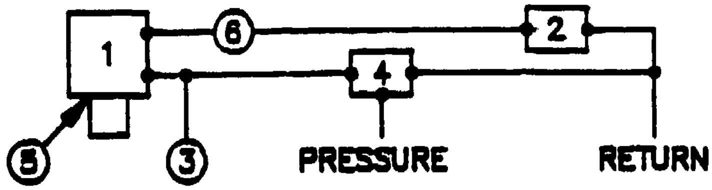
5.1.4 Adjust the pressure regulator to decrease the pressure until the flow reaches 0.025 gpm. Pressure at this condition shall be no less than 2,000 psig.

5.1.5 Close shutoff valve (6).

5.1.6 Adjust pressure at the gauge to 3,000 psig.

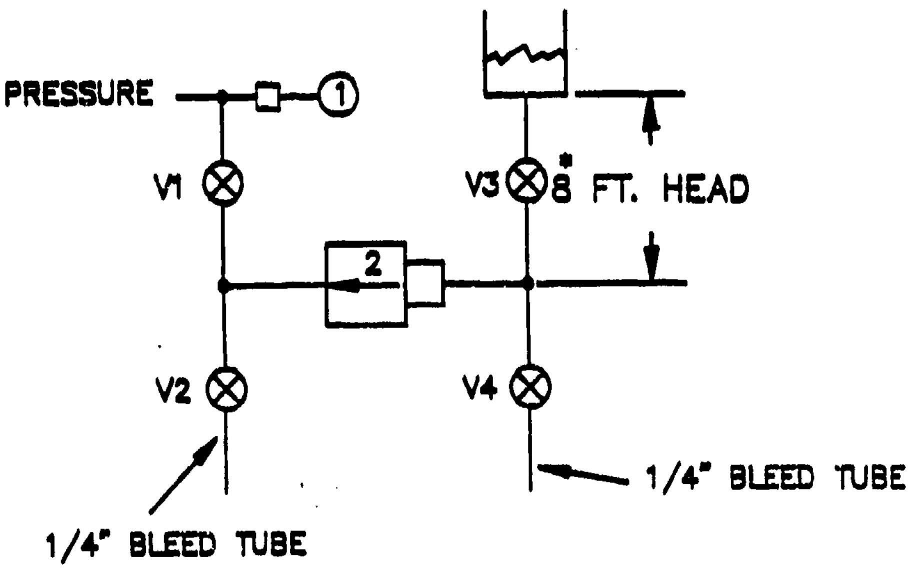
5.1.7 Using a suitable measuring container and timing device, measure the leakage flow from Relief Valve spring cavity (5). This leakage shall fall into the range of 0.15 to 0.40 gpm. Record measured leakage flow at Section 6.1.

5.1.8 Remove tested Relief Valve assembly from fixture block for installation into ISU assembly.



- RETURN PRESSURE 25 PSIG MAX AT ALL FLOWS
- PRESSURE SOURCE – 3500 PSI – 3 GPM MIN
- 1 – TEST RELIEF VALVE/ BLOCK 6599854
- 2 – FLOW METER – RANGE 0.01 TO 3.0 GPM
- 3 – PRESSURE GAUGE – RANGE 0 TO 4000 PSI W/ SNUBBER
- 4 – PRESSURE REGULATOR – RANGE 500 TO 3500 PSI
- 5 – DRAIN FROM RELIEF VALVE SPRING CAVITY
- 6 – SHUTOFF VALVE

FIGURE I



- PRESSURE SOURCE – 3000 PSI – 1GPM
- 1 – PRESSURE GAGE 0 – 4000 PSI W/ SNUBBER
- 2 – TEST CHECK VALVE/ BLOCK 6599855
- V1, V2, V3, V4 – HAND OPERATED SHUT–OFF VALVES
- * USE STATIC HEAD OF 8.0 ±0.5 FT. OR LOW PRESSURE REGULATION TO CONTROL PRESSURE AT CHECK VALVE INLET TO 3.0 ±0.2 PSIG

FIGURE II

5.2 Damper Check Valve

5.2.1 Assemble Damper Check Valve per 6599762, Sheet 1, and install in test fixture 6599855. Make connections per Figure II. Start with all hand valves closed and follow procedures of 5.2.2 and 5.2.3.

5.2.2 Open hand valves V_3 and V_2. A steady column of fluid shall flow from the bleed tube at V_2. Close hand valves V_3 and V_2.

5.2.3 Check that pressure source at gauge (1) is active. Open hand valves V_1 and V_4. Using a suitable container and timing device, measure leakage flow from bleed tube at V_4. This flow shall not exceed 5.0 cc/min. Close V_1 and V_4.

5.2.4 Remove tested Damper Check Valve parts from fixture block for installation into ISU assembly.

5.3 Proof Test - Spring

5.3.1 Complete assembly of ISU per 6599762. Partially fill the spring chamber volume with 2400 cc of Mobil 423 hydraulic oil and seal it. Partially fill the ISU crankcase volume with 1250 cc of Mobil 423 hydraulic oil and seal it. Mount the ISU on the test stand. Complete the load drive and instrumentation attachments.

5.3.2 Apply gradually increasing load to the ISU wheel spindle in the jounce direction. Monitor the resulting pressure in the ISU spring chamber. Increase the external load to bring the spring chamber pressure to 18,000 psig. Hold this condition for five minutes. There shall be no evidence of distress of ISU parts or external leakage from the test unit. Return the external load to zero.

5.4 Spring Curve

NOTE: ISUs to be applied to rear stations 3 through 6 of the vehicle use a "stiffer" spring than those of the forward stations to minimize the effects of cargo load and temperature upon vehicle height. The units differ only in the amount of fluid used in the spring volume and are otherwise identical in physical assembly detail. Where the spring variation affects numerical characteristics in the section which follows, these differences are reflected in Table I.

5.4.1 Using the load stand drive device, position the ISU wheel spindle at its static position (9.38 inches below the crankcase centerline to within 0.02 inches). Charge the crankcase chamber volume with dry nitrogen at a pressure of 80 ±10 psig. Reduce the quantity of fluid in the spring chamber to (A) cc (see Table I). Then charge the spring chamber volume with dry nitrogen at a pressure of (B) psig. Make sure to allow time for the gas pressure to become stable.

TABLE I.

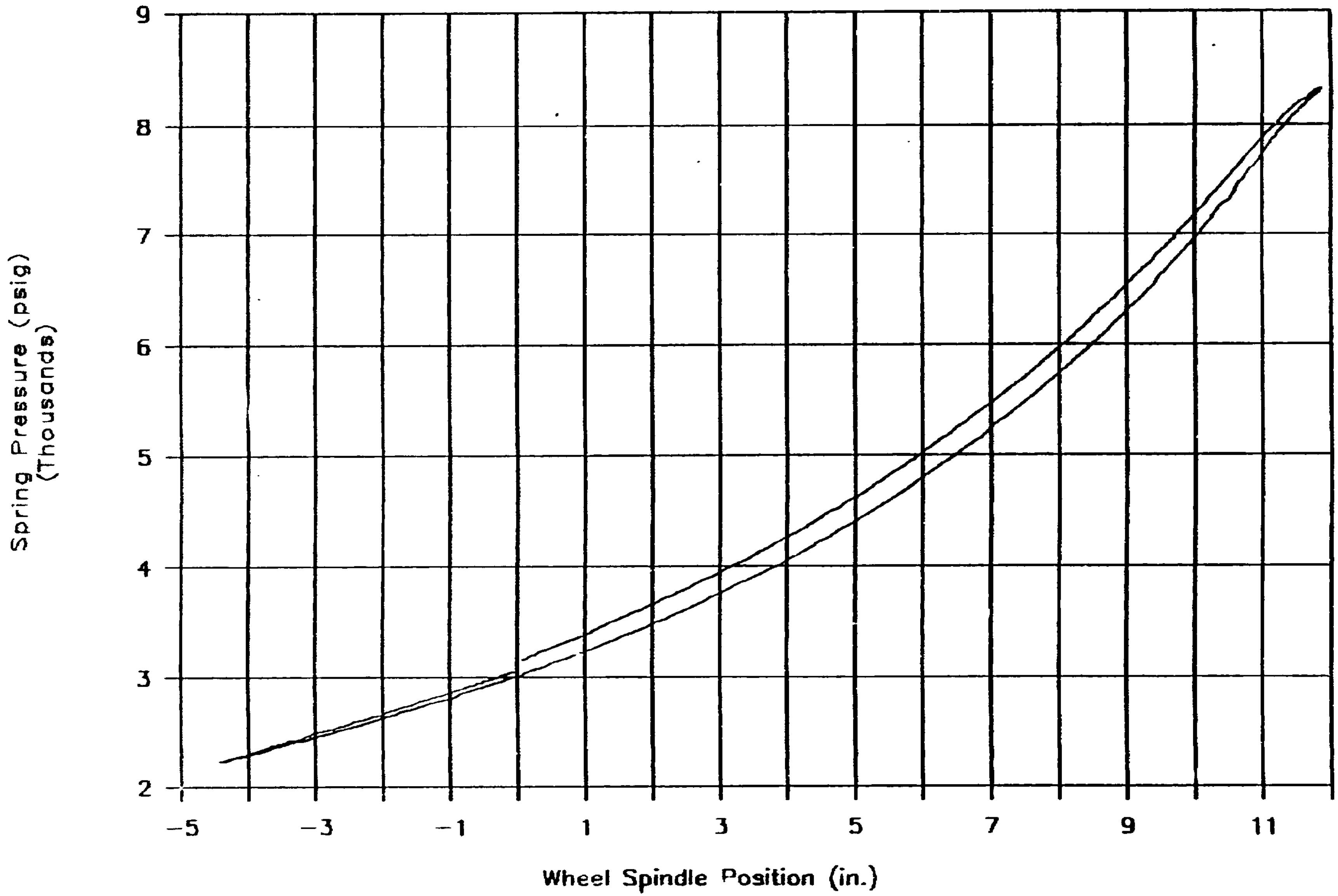
	CHARACTERISTICS	VALUE/UNITS
Forward ISUs		
	(A)	1,650 ±10 cc
	(B)	3,100 ±20 psig
	(C)	5,780 ±60 psig
Rear ISUs		
	(A)	1,950 ±10 cc
	(B)	1,500 ±15 psig
	(C)	3,880 ±40 psig

5.4.2 Reposition the ISU spindle to +11.0 ±0.02 inches. After sufficient time to stabilize (typically several minutes), the spring pressure shall be (C) psi. If too low, add fluid to or, if too high, remove fluid from the spring chamber after removing the gas charge from the chamber. Make adjustments as necessary until the pressure specification is met.

5.4.3 Make the required provisions in the test equipment to drive the ISU roadarm on a sinusoidal basis. Set operating frequency to 0.3 Hz. and peak amplitudes to 11.5 +0.5 inches and 4.5 +0.5 inches in jounce and rebound directions, respectively. Make a run of one complete cycle starting from the static (zero) position and proceeding first toward jounce. Plot the variable pressure present in the spring chamber as a function of roadarm position. Figures IIIa and IIIb show typical spring pressure curves for forward and rear station ISUs, respectively. The plot for the test ISU shall fall within the limits depicted in Figures IVa or IVb as appropriate.

FIG IIIa SPRING PRESSURE / POSITION

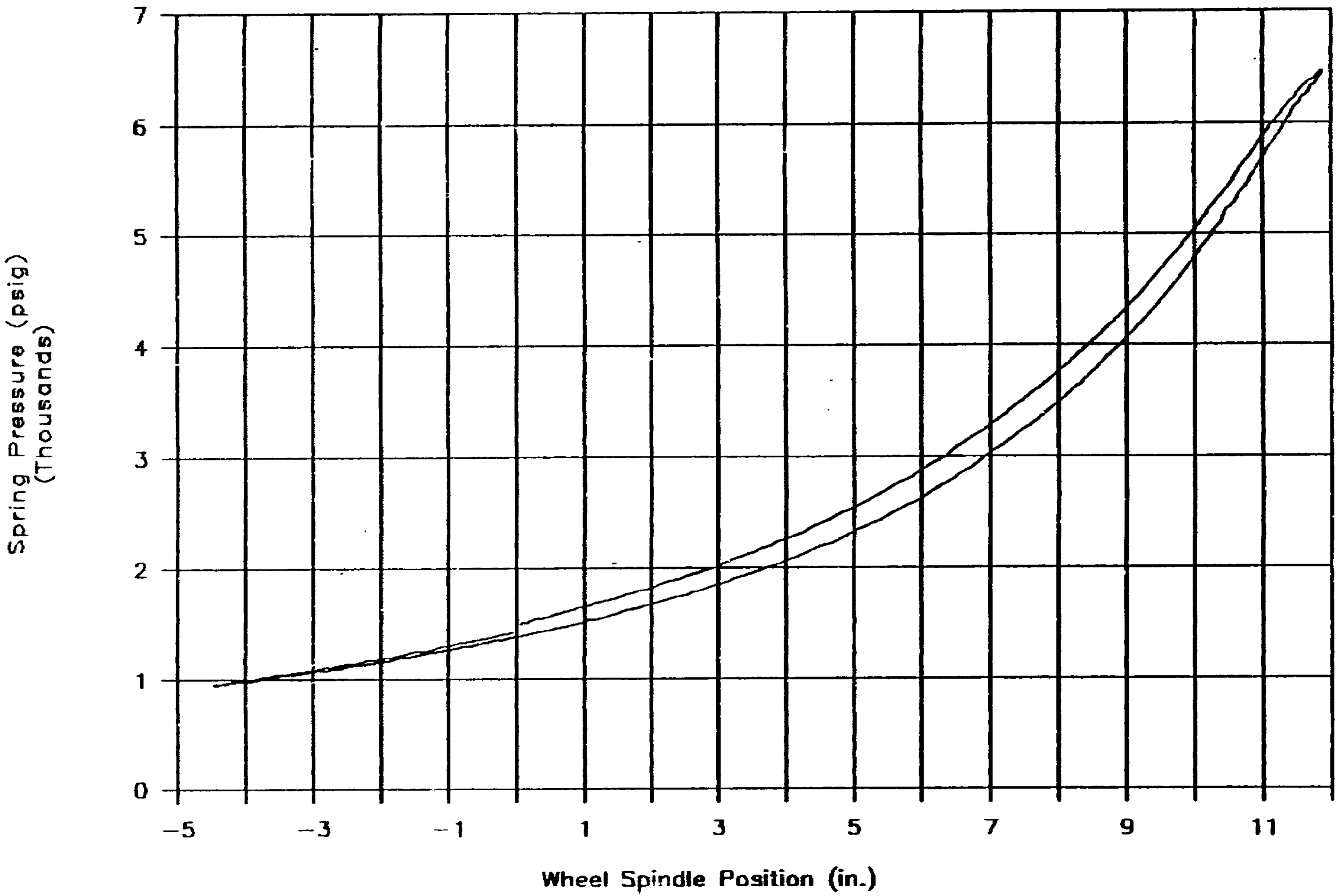
AAV–7 ISU Forward Stations



Drawing No. 6599850

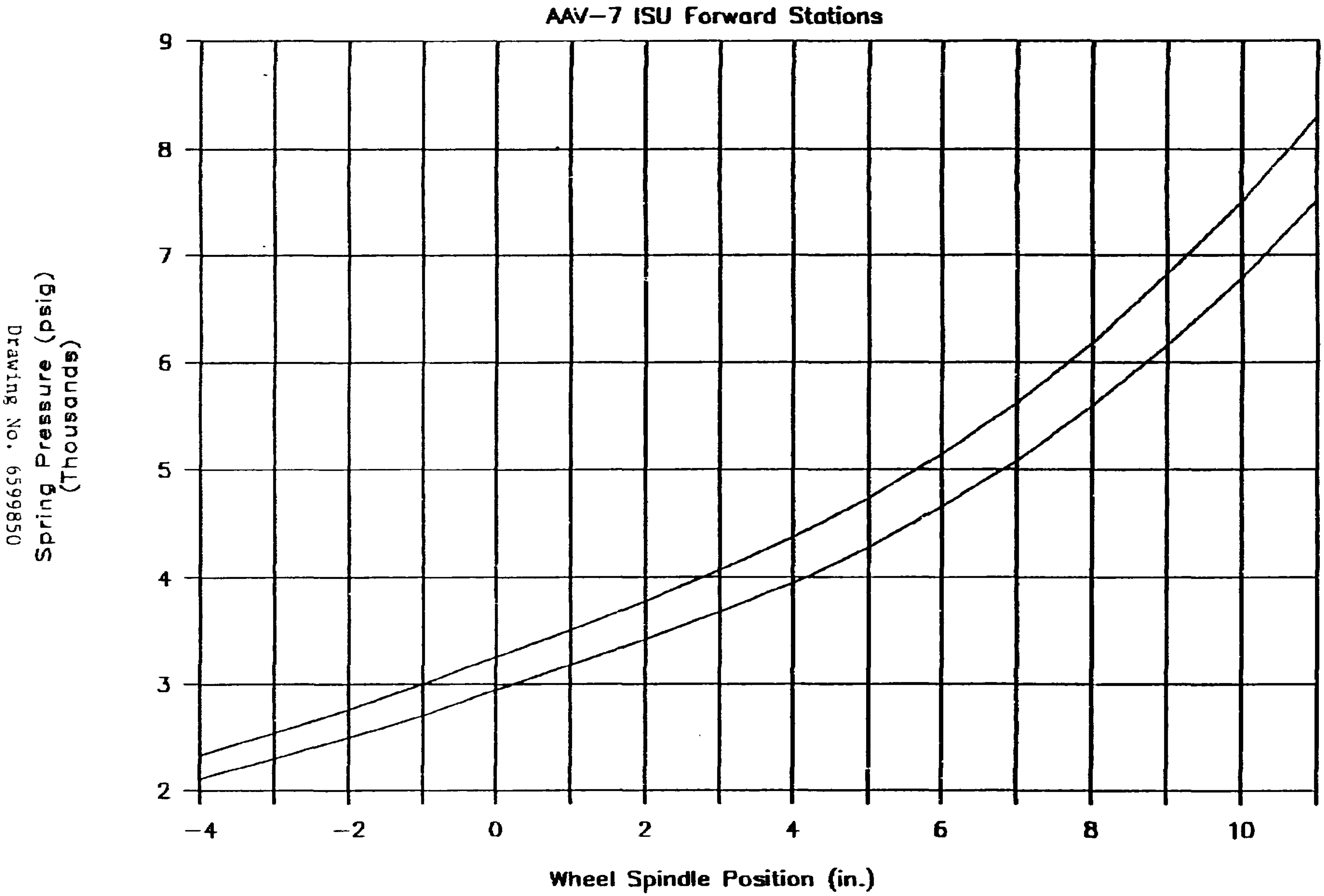
FIG IIIb SPRING PRESSURE / POSITION

AAV–7 ISU Rear Stations



Drawing No. 6599850

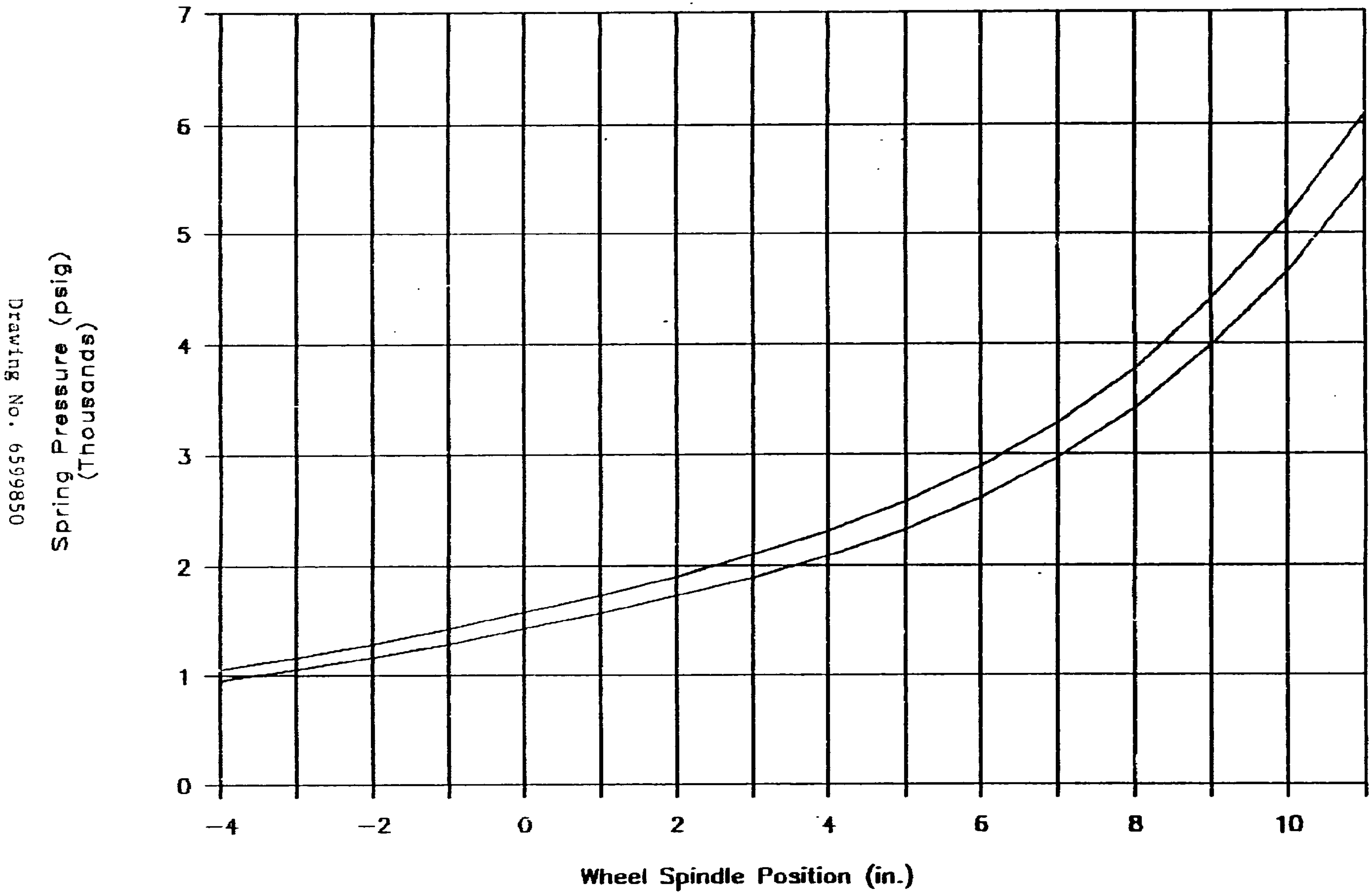
FIG IVa SPRING PRESSURE LIMITS



Drawing No. 6599850

FIG IVb SPRING PRESSURE LIMITS

AAV–7 ISU Rear Stations



Drawing No. 6599850

5.5 Combined Spring/Damper Curve

NOTE: Proper operation of the ISU damper will be achieved only after complete priming of the damper pump has been accomplished. It may be necessary to operate the ISU on a cyclical basis for a short time to effect complete evacuation of unwanted air from the pump circuit prior to continuing with the performance tests which follow.

5.5.1 Drive the ISU roadarm as described in 5.4.3. Plot the variable vertical load present at the roadarm wheel spindle as a function of roadarm position. Figures Va and Vb show typical wheel spindle load curves for forward and rear station ISUs respectively. Proper damper operation will be indicated by the spread between vertical wheel spindle loads for jounce and rebound directions of motion. The test ISU shall conform in this respect to the characteristics depicted in Table II. This requirement applies equally to front and rear station ISUs.

TABLE II.

WHEEL SPINDLE POSITION	DIFFERENTIAL LOAD
-4.0 inches	5,000 lbs. min.
+3.0 inches	2,000 lbs. max.
+11.0 inches	5,000 lbs. min.

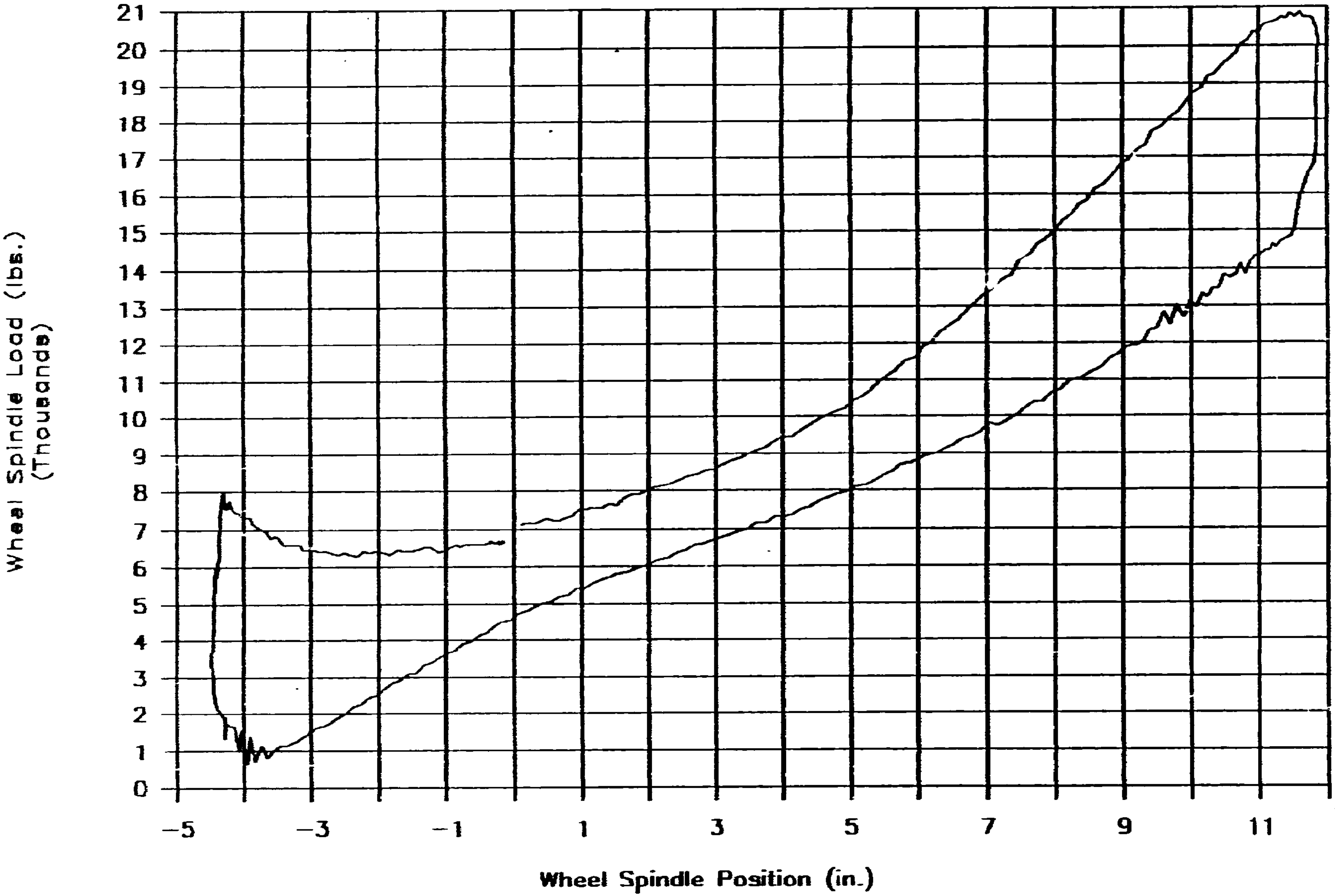
5.5.2 Drive the ISU roadarm as described in 5.4.3 except that the frequency of operation shall be 0.1 Hz. Plot the variable vertical load present at the roadarm wheel spindle as a function of roadarm position. Figure VIa and VIb show typical wheel spindle load curves for forward and rear station ISUs respectively. No point on the load curve taken at this frequency shall fall into the negative load region for either ISU configuration.

5.6 Limited Durability

5.6.1 Drive the ISU roadarm using the cycle simulation described in 3.1.8 as input to the drive system. Monitor the temperature experienced at the lower edge

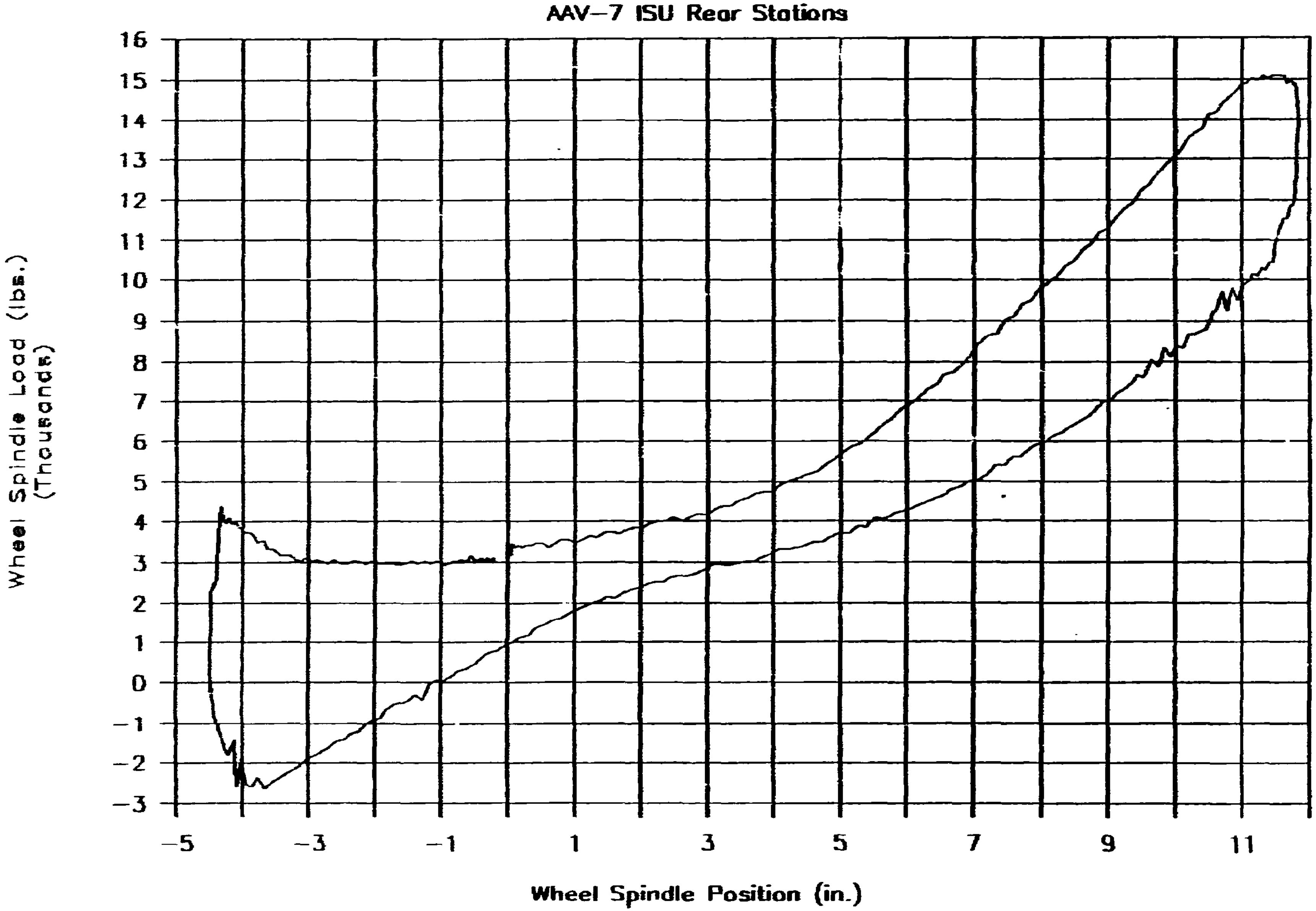
FIG Va WHEEL LOAD/POSITION

AAV-7 ISU Forward Stations



Drawing No. 6599850

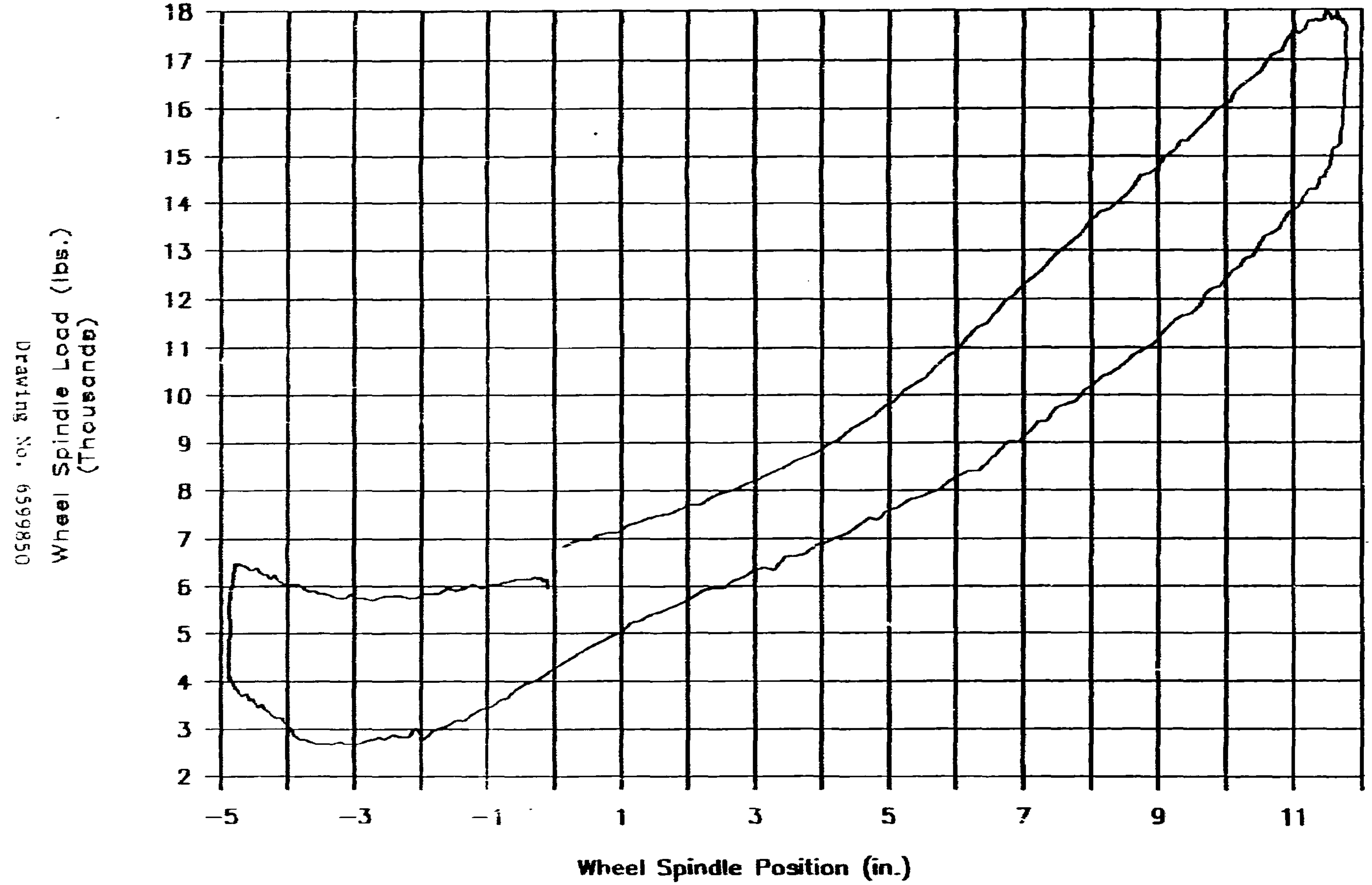
FIG Vb WHEEL LOAD/POSITION



Drawing No. 6599850

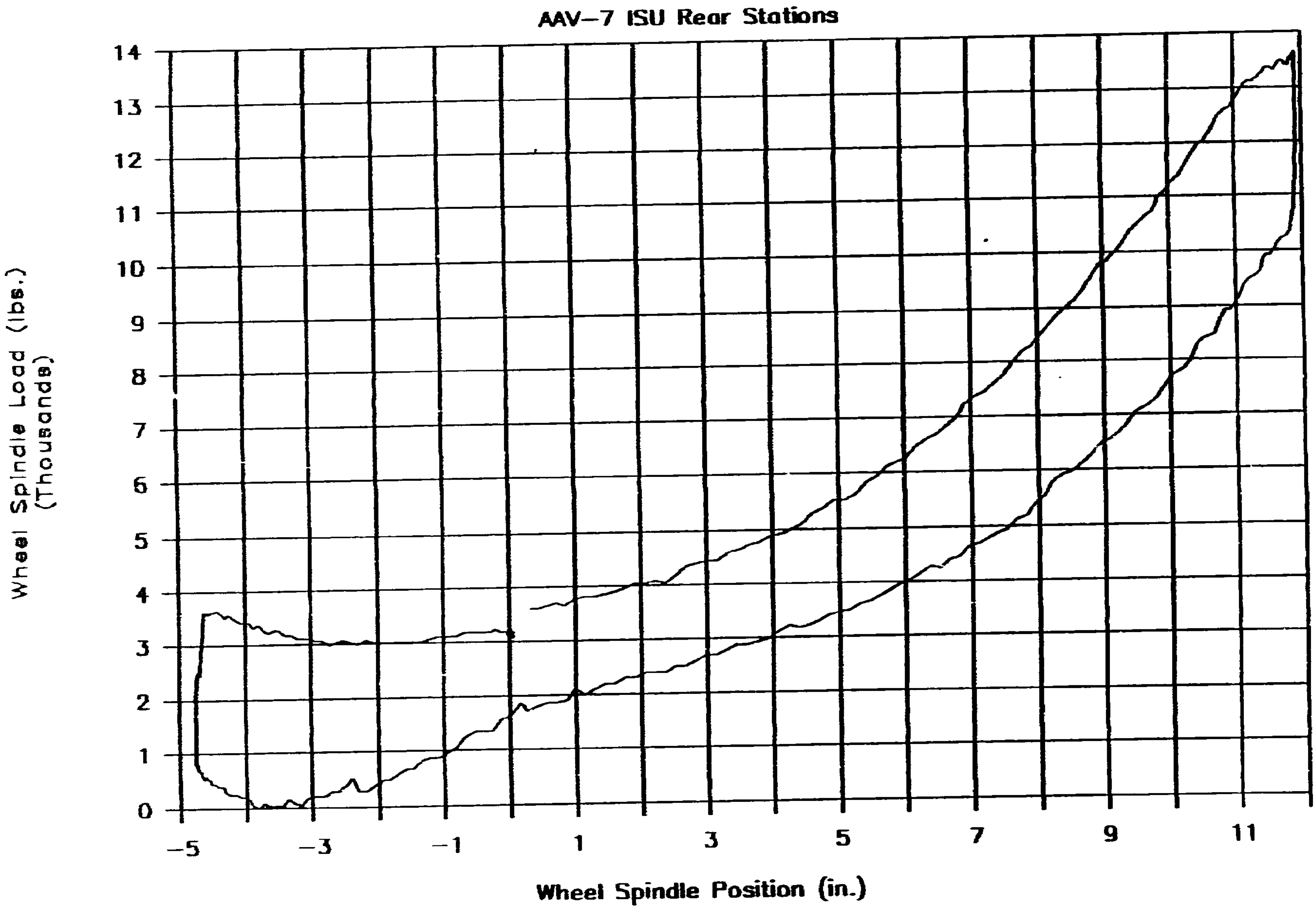
FIG VIa WHEEL LOAD/POSITION

AAV–7 ISU Forward Stations



Drawing No. 6599850

FIG VIb WHEEL LOAD/POSITION



Drawing No. 6599850

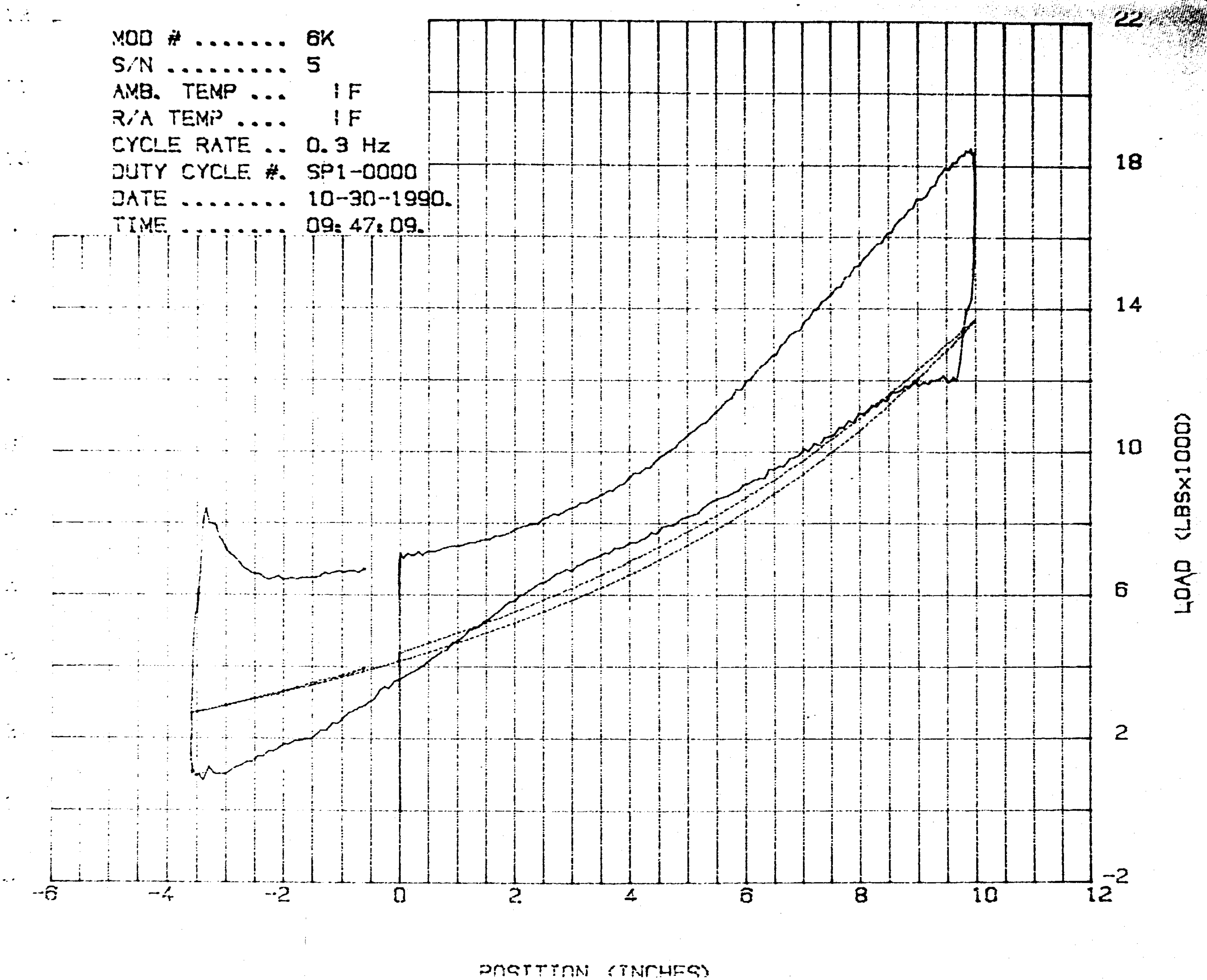
of the torque cover face. Do not allow this temperature to exceed 160°F and, to this end, use as required the air flow of a large fan directed across the face of the ISU to maintain this condition. Operate the ISU for 10 hours minimum.

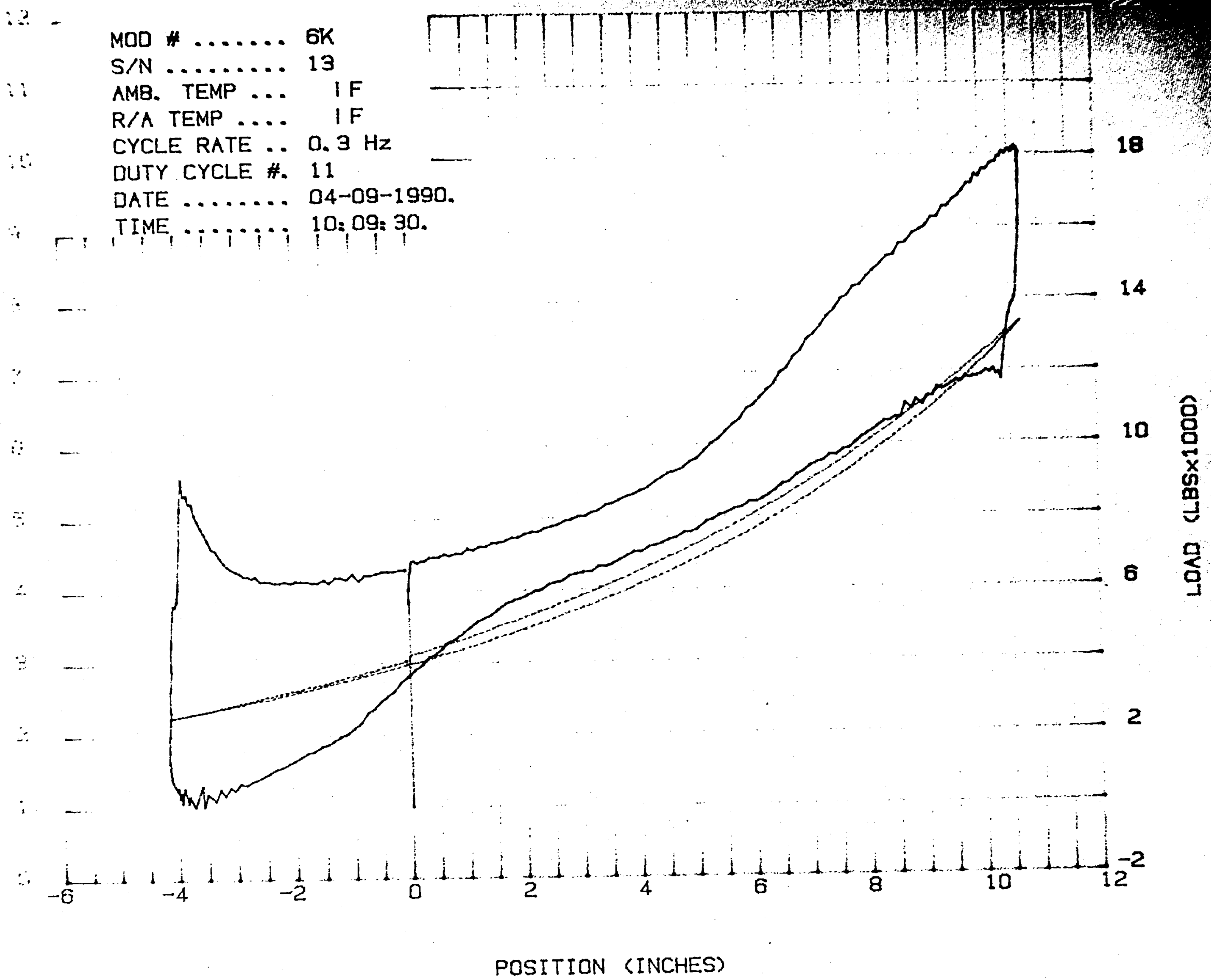
5.6.2 Allow the test ISU to cool to 80 ±10 F. Check the gas pressure in the spring volume. This pressure shall not be less than 90% of its initial value (this much "loss" due to gas entrainment in the fluid is typical). Check the gas pressure in the ISU crankcase. It shall be within ±15% of its initial nominal value.

5.6.3 Repeat the tests of 5.5.1 and 5.5.2. The ISU shall meet the requirements of those tests as before.

APPENDIX D

SPRING AND DAMPER CURVES

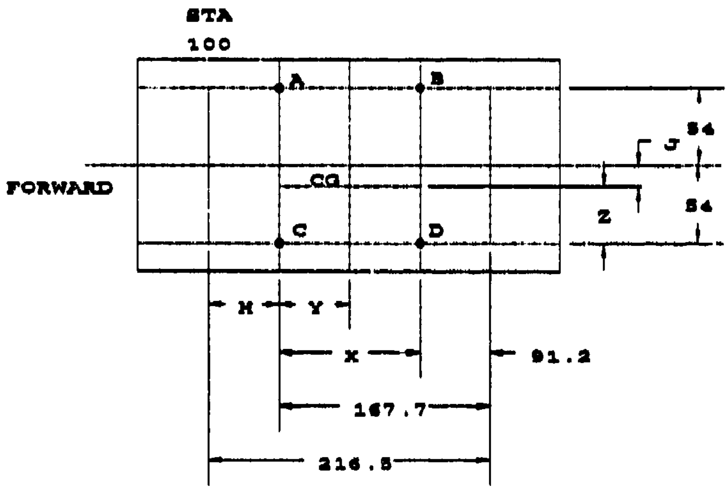

MOD # 6K
S/N 5
AMB. TEMP ... !F
R/A TEMP .... !F
CYCLE RATE .. 0.3 Hz
DUTY CYCLE #. SP1-0000
DATE .... 10-30-1990.
TIME .... 09:47:09.
LOAD (LBSx1000)
22
18
14
10
6
2
-2
-6
-4
-2
0
2
4
6
8
10
12
POSITION (INCHES)


MOD # 6K
S/N 13
AMB. TEMP ... I F
R/A TEMP .... I F
CYCLE RATE .. 0.3 Hz
DUTY CYCLE #. 11
DATE .... 04-09-1990.
TIME .... 10:09:30.
18
14
10
6
2
-2
LOAD (LBS×1000)
-6
-4
-2
0
2
4
6
8
10
12
POSITION (INCHES)

APPENDIX E

VEHICLE CG CALCULATIONS

LVPT-7 Center of Gravity Calculations



F_A = 8,524
F_B = 9,998
F_C = 9,932
F_D = 9,776

F_T = 38,230 pounds total vehicle weight (with fuel tank near empty)
X = (167.7 - 91.2) = 76.5 inches
$(F_A + F_C)(Y) = (F_B + F_D)(76.5 - Y)$

Substituting,
18,456(Y) = 19,774(76.5 - Y)
38,230(Y) = 1,512,711
Y = 39.6
H = (216.5 - 167.7) = 48.8

CG Location = 48.8 + 39.6 = 88.4 or Station <u>188.4</u> inches longitudinal

$(F_C + F_D)(Z) = (F_A + F_B)(108 - Z)$

Substituting,
19,708(Z) = 18,522(108 - Z)
38,230(Z) = 2,000,376
Z = 52.3
J, then, = 54 - Z = <u>1.7</u> inches to port of centerline

APPENDIX F

STATEMENT OF WORK
FOR
VEHICLE UPWEIGHTING

STATEMENT OF WORK

SCOPE OF EFFORT

The contractor will be responsible for all manpower, services, and supplies to securely install steel ballast plates in a USMC Assault Amphibian Vehicle. Nine (9) plates, each with dimensions of 36" W x 72" L x 2" H (total weight of approximately 14,000 pounds) will be provided by the Government at time of purchase award.

The steel ballast plates shall rest in a contractor fabricated cradle/basket resting on the floor plates or floor support beams/stringer of the vehicle. The cradle shall be secured to four corners of the troop compartment. The ballast plates and cradle, when secured, shall be capable of sustaining 3g loading in any direction without moving or causing damage to the vehicle or supporting structure. Vehicle systems or components may not be moved or altered for this installation. The contractor shall determine floor loading criteria and limits so as not to damage or overload the floor structure. The ballast plates may be secured to one another, but must be removable through the 60" x 108" cargo hatch opening in increments or sections that do not weigh more than 5000 pounds each (to be liftable by crane). The ballast plates shall be modified by the contractor so that they are equipped with lifting points or attachment hardware to facilitate lifting. The ballast weight shall be centered at a point ** inches aft of the vehicle sprocket centerline and along the vehicle fore-aft centerline. Vertical position need not be considered.

The contractor will be responsible for transportation of the Government test vehicle from its current location (Warren, Michigan) to the contractor's facility for ballasting, and back. While the vehicle is in the contractor's facility, the contractor will be responsible for all maintenance and operation of the vehicle, including driving the vehicle on and off the delivery truck. The contractor will be responsible for showing proof that qualified drivers will be used when driving the test vehicle.

These services shall be performed within 30 days of purchase order award. A pre-inspection of the vehicle is not possible.

APPENDIX G

RIDE METER DESCRIPTION AND OPERATION

ABSORBED POWER METER

by A. Wroble 14 Sept, 1989

DESCRIPTION

The absorbed power meter consists of an accelerometer, main processor unit, a remote meter panel with start-stop switch, and associated cables. The unit provides the capability of reading: (1) the time duration (up to 120 seconds) between a start and stop signal of a run, (2) the peak instantaneous acceleration in gravity units during that run (up to 12 G's), (3) the accumulated absorbed energy (up to 1200 watt-seconds in the X10 position) during that run. The average absorbed power in watts is calculated by dividing the accumulated energy in watt-seconds by the run duration in seconds.

In addition, the instrument provides analog voltage input and outputs for external recording devices. The analog output signals available are the instantaneous acceleration in gravity units or foot per second-squared units, and the instantaneous absorbed power in watts. A properly scaled analog recording of instantaneous acceleration can be fed into the instrument to determine the average absorbed power during any selected time segment of the recording.

OPERATION

The instrument requires nominal military vehicle power of 18-30 volts DC at approximately 200 milliamperes. The unit is current protected with a 1/2 ampere fast blow SB fuse and voltage protected against application of reverse polarity.

Power is applied to the unit when the power leads are connected and is verified by noting the presence of digits and yellow backlighting on the remote meter. The red power lead must be connected to positive battery voltage, and the black power lead must be connected to negative battery voltage, which is assumed to be vehicle ground.
CAUTION: This unit should not be used on a vehicle with the positive battery terminal connected to ground, unless special provisions are made to insulate all elements of the instrument from vehicle ground.

It is necessary to place a jumper between the RED banana jacks labelled ACC OUT and TAPE IN on the main panel for proper meter operation, unless acceleration data is fed in from an external analog recorder.

The remote panel meter switch should be placed in the TIME position. This is done to assure that the timer is stopped. If it is running, the operator should quickly depress and release the START-STOP button to stop the timer. Then the operator should set the main unit range switch in the X1 position for
smooth to moderate terrain, or in the X10 position for rough

terrain. Changing the range switch during or after the measurement run invalidates the run data because it controls the rate of the energy averaging process and not the meter scale factor. The range switch affects only the scale factor of the energy and power units, WATT-SEC and ABRB PWR OUT, and not the TIME or PEAK ACCEL readings. In the X1 position the unit reads directly in watt-seconds. In the X10 position the scale reading must be multiplied by 10 to obtain the correct total energy reading. For example, a meter reading of 098.3 watt-seconds with the range switch in the X10 position should be interpreted as a value of 983.0 watt-seconds. Just prior to the start of the run, the RESET button on the remote panel meter should be depressed and held for about one second to insure complete reset of all the functions. Subsequently, on any of the functions, a stationary reading of ±0.1 at the start is considered acceptable.

The operator determines the start of the run by quickly depressing and releasing the hand held START-STOP button. This starts the timer, the peak acceleration acquisition, and the energy accumulation process. The three position meter switch can select PEAK ACCEL or TIME or WATT-SEC. If the meter is in the TIME position during the run, the operator can choose to stop the run based on the timer reading. The run is terminated when the operator quickly depresses and releases the START-STOP button again. It is recommended that the three readings be taken and recorded together with the range switch position within one minute after the completion of the run. Since the readings are held in analog form, a small amount of drift is inevitable.

In the TIME position, the meter reads in seconds and tenths of seconds up to a maximum of 120.0 seconds. In the PEAK ACCEL position the meter reads in G's and tenths of G's up to a maximum of 12.0 G's. In the WATT-SEC position with the range switch (on the main unit) set at the X1 position, the meter reads in watt-seconds and tenths of watt-seconds to a maximum of 120.0 watt-seconds. With the range switch in the X10 position, the meter reads in units of ten watt-seconds to a maximum of 1200 watt-seconds. For example, a reading of 107.5 represents 1075 watt-seconds. The meter may indicate readings higher than the above maximum values, but those values are close to meter saturation and should not be trusted. It would be better to suitably modify the run and retake the data. Once the data has been noted or recorded, the operator may reset the instrument by depressing the RESET button to clear the meter.

The average absorbed power in watts is calculated by dividing the accumulated energy in watt-seconds (determined from the meter reading and the range switch) by the run time in seconds.

ADDITIONAL FUNCTIONS

The ACC OUT (accelerometer output) banana jack pair provides a zero based, bipolar, analog voltage output scaled at 1.0 G per volt, with an upward acceleration represented by a positive voltage on the red jack with respect to the grounded black jack. This signal can by recorded during a run and played back for analysis at a later time. If the connection between the ACC OUT and TAPE IN is maintained, this signal can be recorded during a normal measurement run. The output limits are ±12 G's or volts. The load impedance should not be less than 5000 ohms.

The TAPE IN (analog acceleration signal) banana jack pair provides a method to determine the instantaneous and average absorbed power for any segment of pre-recorded acceleration data. The recording medium is assumed to be tape, but any medium including digital can by used so long as the resulting signal is converted to analog form, has the proper scale factor, and contains the original frequency information from 0.1 to 50 Hertz. The scale factor, polarity, and limits are the same as those of the ACC OUT.

In order to use this input, the shorting jumper between ACC OUT and TAPE IN must be removed. A properly scaled analog acceleration signal from a data recorder must be connected to TAPE IN terminals, ground to black and signal output to red. NOTE: All black banana jacks are tied together and connected to the instrument case ground, which is normally connected to vehicle ground. Operation in this mode proceeds the same as an actual run: Make sure the timer is not running; RESET to start the measurement when desired; press the START-STOP button again to stop the run; note and record the three readings and the range switch setting; stop the playback device; calculate the average absorbed power.

The FIL ACC OUT (filtered acceleration output) banana jack pair is provided for use with a visual recording device such as a strip chart recorder or oscilloscope. The FIL ACC OUT signal is the accelerometer signal rescaled to feet per second squared and filtered to remove frequencies above 360 Hertz. The scale factor is 10 feet-per-second-squared/volt and the output limits are ±120 feet-per-second-squared or ±12 volts. The load impedance on this output should not be less than 5000 ohms.

The ABRB PWR OUT (absorbed power output) banana jack pair is also provided for use with a visual recording device. This signal is a measure of the instantaneous absorbed power before the mathematical averaging process. The scale factor of this signal is 0.1 watt/volt with the range switch in the X1 position and 1.0 watt/volt with range switch in the X10 position. In either case, the output limit is 12 volts. The load impedance on this output should not be less than 5000 ohms.

CALIBRATION

There are a total of eight calibration adjustments in this instrument. They are all accessible from the front panel. These adjustments can be divided into two categories; routine calibration and component replacement calibration. Routine calibration should be performed on the following: ACCEL OFFSET and GAIN, SQR OFFSET, WATT-SEC OFFSET, TIME OFFSET, and TIME CAL. Component replacement calibration includes routine calibration plus the adjustment of X1 CAL and WATT-SEC CAL. These repairs and adjustments should be made only be a factory trained technician. This calibration is necessary only after internal components have been replaced due to component failure or when response to routine calibration is improper.

Routine Calibration Procedure

There is considerable variation in scale factors and offsets among the accelerometers used with this instrument. This instrument can be adjusted to compensate for these accelerometer variations. It is therefore necessary to associate a particular accelerometer with each instrument, and include that accelerometer in the routine calibration procedure.

The unit should be connected to a 24 ±1 volt DC power supply with at least a 250 milliampere capacity.

All cables should be properly connected, including the accelerometer and its cable.

The ACC OUT - TAPE IN jumper should be in place.

Accel Gain and Accel Offset:

Connect a DC multi-voltmeter with 0.5% or better accuracy across the FIL ACC OUT terminals.

Place the accelerometer on a firm surface to sense vertical acceleration in the same direction as installed in a vehicle.

Adjust ACCEL OFFSET until the voltmeter reads within 3 millivolts of zero.

Place the accelerometer so that its sense axis is parallel to the horizon. (Lay it on its side.)

Adjust ACCEL GAIN until the voltmeter reads within 15 millivolts of -3.22 volts. If the voltage is positive, the sense axis of the accelerometer is reversed. (Rewire by flipping the output leads on the accelerometer connector.)

A certain amount of interaction between the above adjustments can be expected. Continue by alternating between the two adjustment procedures until both conditions are met.

Disconnect the multi-voltmeter from the unit.

Sqr Offset:

Connect a DC multi-voltmeter with 0.5% or better accuracy across the ABRB PWR OUT terminals.

Remove the jumper between ACC OUT and TAPE IN terminals.

Short circuit the TAPE IN terminals with the jumper.

Adjust SQR OFFSET until the voltmeter reads within 3 millivolts of zero.

Disconnect the multi-voltmeter from the unit.

Watt-Sec Offset:

Short circuit the TAPE IN terminals.

Place the instrument panel meter switch in the TIME position.

Press the reset button to reset the timer.

If necessary, operate the START-STOP button to stop the timer.

Move the panel meter switch to the WATT-SEC position.

Adjust the WATT-SEC OFFSET to reduce the drift of the least significant digit of the panel meter to less than once in ten seconds. It is not necessary for the meter to be reading zero for this adjustment. As a final check, RESET the panel meter, and note the time it takes to register a least significant digit change. If it is less than 10 seconds, perform a readjustment.

Time Offset and Time Cal:

Place the instrument panel meter switch in the TIME position.

Press the RESET button to reset the timer.

If necessary, operate the START-STOP button to stop the timer.

Adjust the TIME OFFSET to reduce the drift of the least significant digit of the panel meter to less than once in ten seconds. It is not necessary for the timer to be reading zero for this adjustment. As a final check, RESET the panel meter, and note the time it takes to register a least significant digit change. If it is less than 10 seconds, perform a readjustment of the TIME OFFSET.

When the offset adjustment is satisfactory, RESET the timer.

Using a stopwatch or clock with a sweep second hand as a reference standard, operate the timer for 60 seconds using the START-STOP switch.

If the timer reading differs from 60.0 seconds by more than 0.3 seconds, make a one turn adjustment of TIME CAL.

RESET and rerun the timer again for 60 seconds.

Note the time difference that one turn made, and make a proportional corrective adjustment of TIME CAL.

Continue the above procedure until the timer reads 60.0 ±0.3 seconds.

This concludes the routine calibration procedure.

COMPONENT REPLACEMENT CALIBRATION

After a component is replaced, the routine calibration procedure must be completed first before performing this calibration procedure.

X1 Calibration:

Connect an oscillator operating at 10 ±1 Hz sine wave into the TAPE IN terminals.

Set unit range switch to X10.

Connect a slow multi-voltmeter across ABRB PWR OUT banana jacks.

Adjust the oscillator sine wave amplitude for a reading of 0.5 ±.05 VDC on the 10 volt scale of the multi-voltmeter, and note the multi-voltmeter reading.

Set unit range switch to X1.

Adjust X1 CAL so that the new meter reading is just ten times the noted previous reading.

WATT-SEC Calibration:

Connect an oscillator operating at 10 ±1 Hz sine wave into the TAPE IN terminals.

Set unit range switch to X10.

Connect a slow multi-voltmeter across ABRB PWR OUT banana jacks.

Adjust the oscillator sine wave amplitude for a reading of 0.5 ±.05 VDC on the 10 volt scale of the multi-voltmeter, and note the multi-voltmeter reading.

Place the instrument panel meter switch in the TIME position.

Press the RESET button to reset the timer.

If necessary, operate the START-STOP button to stop the timer and RESET it to zero.

Operate the timer for 100.0 seconds using the START-STOP switch.

Move the panel meter switch to the WATT-SEC position.

The WATT-SEC reading on the panel meter should be 100 times the reading in the multi-voltmeter. For example, if the multi-voltmeter reads 0.524, the WATT-SEC panel meter should read 52.4 ±0.3 units.

If the panel meter reading differs from 100 times the multi-voltmeter reading, make a one turn adjustment of WATT-SEC CAL.

Continue the above procedure until the watt-sec panel meter reads 100 ±1 times the reading on the multi-voltmeter.

This concludes the total instrument calibration procedure.

APPENDIX H

VEHICLE TEST PLAN

ADVANCED DEMONSTRATION

TEST PLAN

for a

HYDROPNEUMATIC SUSPENSION SYSTEM

mounted on an

ASSAULT AMPHIBIAN VEHICLE (LVTPX-12)

Prepared By:

David Taylor Research Center
Marine Corps Programs Office
Bethesda, Maryland

August 6, 1990

TABLE OF CONTENTS

1.0 - INTRODUCTION

1.1 Background:

Developments in advanced suspension systems are seeking to demonstrate the feasibility of using hydropneumatic suspension systems to provide improved ride quality and load carrying capability in USMC amphibian vehicles. In place of the standard torsion bar and shock absorber system of the AAV-7A1 Assault Amphibian Vehicle, a test vehicle has been modified with an in-arm, externally mounted hydropneumatic suspension system. This system should provide superior ride quality, improved load carrying capacity, and require less suspension system maintenance.

Hardware tested and experience gained from this system will be applicable to the AAV family for improved load carrying capability and the Advance Amphibious Assault (AAA) program. This future family of vehicles may require new vehicle systems currently under development (including hydropneumatic suspension systems) to accomplish their mission.

This revision of the test plan has been greatly modified from previous versions due to redirection in test scope. The reader is referred to Appendix B and the listed documents for technical discussion of the hardware.

1.2 Purpose:

The purpose of this document is to provide a test plan for testing of a modified Assault Amphibian Vehicle (prototype LVTPX-12-10 chassis) with an in-arm hydropneumatic suspension system. This program of hardware development and testing is in support of the AAV-7A1 Product Improvement Program, sponsored by the Program Manager - AAA (DRPM AAA) and managed by the Marine Corps Programs Office of the David Taylor Research Center (Code 1240).

1.3 Program Office Representative:

Any questions or concerns with this test plan should be directed to the following persons:

Mr. Michael Gallagher
David Taylor Research Center
Code 1240
Bethesda, Maryland 20084-5000

Phone: Autovon 287-1852
Commercial (301) 227-1852

2.0 - TEST PROGRAM

2.1 Test Objective:

The objective of testing will be to accumulate up to 6000 miles of operation (one life cycle) on the suspension system. The vehicle shall be operated through a normal vehicle profile (20% Water Operation, 80% Land Operation). After this time, a determination will be made to continue testing, or to remove the suspension units for teardown inspection and/or refurbishment.

The primary objective is to operate the vehicle in a real world environment to assess the suspension systems operability and maintainability. It is requested that the vehicle be operated 500-600 miles per month.

The secondary test objective is to establish the performance capabilities of this system, to allow the Marine Corps to make an acquisition decision on whether further development and acquisition is warranted.

2.2 Scope of Test:

The AAV/HSS tests will be conducted at the Amphibian Vehicle Test Branch (AVTB), Camp Pendleton, California, by AVTB personnel (or at other facilities and/or personnel contracted by AVTB). Spare parts unique to the suspension system and the vehicle installation will be provided with the test vehicle. Any maintenance that will require disassembly of the suspension unit will be provided by the contractor at his facility. With the delivery of the test vehicle will be two spare suspension units (one port, one starboard). Damaged suspension units, or units in need of repair, shall be shipped to the contractor for rework.

Vehicle operation is to occur on both land (over various terrains) and in the water. AVTB will be responsible for structuring of tests and determination of how each test should be conducted. AVTB will be responsible for utilizing applicable test procedures from previous or similar testing and for developing any new test plans and procedures. For any outside facilities required, AVTB shall be responsible for arranging and scheduling their use. Baseline testing shall be performed under all climatic conditions and varied terrains to the maximum extent possible.

For tests that involve comparative analysis with the baseline AAV7A1, test criteria will be performed for both the test vehicle and a baseline vehicle. In the event a baseline AAV7A1 has performed and documented the same type test (at equivalent configuration), the test does not need to be repeated for that vehicle.

2.3 Test Phases:

Testing for the vehicle should include a training and familiarization phase for the crews prior to the operational phase. There is no prescribed characterization testing or system tuning for this vehicle as called for under this test plan. Allotted time for all testing at AVTB is approximately one year. Additional durability testing may be run afterwards, with that determination based on initial test results.

The following types of testing are to be conducted and test data accumulated on the AAV/HSS by AVTB:

- Ride Quality
- Crocs Country Test Course
- Amphibious Compatibility
- Vehicle Handling Comparison
- Baseline Vehicle Requirements
- Design Requirements
- RAM-D Tests (500 miles)
- Towing Test

2.4 Schedule:

This test plan is applicable to the performance testing and operational running of the AAV/HSS for approximately one year. Following this, testing may be extended for one additional year for additional durability testing.

On-site contractor support will be provided during initial operation of the vehicle/suspension system, and as an on-call basis during the period of testing. No additional training requirements are anticipated for this system.

As a result of the July-August Test Planning Meeting at AVTB, the following prioritization and scheduling of testing (subject to test range and test hardware availability) shall be conducted:

AAV/HSS Test Schedule

<u>Phase Ia - AVTB Testing</u> (1 Aug - 18 Aug 1990)

Ride Quality	Test 3.3.1
Cross Country Test Course	Test 3.3.2
Vehicle Handling Comparison	Test 3.3.4
Baseline Vehicle Requirements	Test 3.3.5 (a,b,e,f)
Design Requirements	Test 3.3.6 (a,b,c,d,e)
RAM-D Tests (500 miles)	Test 3.3.7

<u>Phase Ib - Hot Weather Testing</u> (19 Aug - 7 Sept 1990)

Ride Quality	Test 3.3.1
Cross Country Test Course	Test 3.3.2
Vehicle Handling Comparison	Test 3.3.4
Baseline Vehicle Requirements	Test 3.3.5 (a,b,e,f)
Design Requirements	Test 3.3.6 (a,b,c,d,e)
RAM-D Tests (500 miles)	Test 3.3.7

<u>Phase Ic - AVTB Testing</u> (8 Sept - 15 Nov 1990)

Amphibious Compatibility	Test 3.3.3 (no surf)
Design Requirements	Test 3.3.6
RAM-D Tests (1000 miles)	Test 3.3.7
Towing Test	Test 3.3.8

<u>Phase Id - Mud/Clay Testing</u> (15 - 30 Nov 1990)

Cross Country Test Course	Test 3.3.2
Vehicle Handling Comparison	Test 3.3.4
Baseline Vehicle Requirements	Test 3.3.5
Design Requirements	Test 3.3.6
RAM-D Tests (500 miles)	Test 3.3.7
Towing Test	Test 3.3.8

<u>Stop Testing</u> (1 - 30 Dec 1990)

Install new dust seals at CGT

AAV/HSS Test Schedule
(continued)

Phase Ie - High Surf Testing (1 - 30 Jan 1991)

Amphibious Compatibility	Test 3.3.3 (surf ops)

Phase If - Cold Weather Testing (1 - 28 Feb 1991)

Ride Quality	Test 3.3.1
Cross Country Test Course	Test 3.3.2
Vehicle Handling Comparison	Test 3.3.4
Baseline Vehicle Requirements	Test 3.3.5 (a,b,d,e)
Design Requirements	Test 3.3.6 (a,b,c,d,e)
RAM-D Tests (500 miles)	Test 3.3.7

Phase Ig - Normal Testing (1 - 31 Mar 1991)

RAM-D Tests (3000 mile mark)	Test 3.3.7
Complete any other tests	

Issue Interim Report due 31 March 1991

Phase II - Normal Testing (1 Apr 1990 - ???)

Design Requirements	Test 3.3.6
RAM-D Tests (6000 mile mark)	Test 3.3.7

2.5 Limited Technical Inspection and Configuration of Vehicle:

Upon the vehicle's arrival at AVTB, it is requested that a Limited Technical Inspection be performed to validate that the vehicle engine/transmission/drivetrain systems are capable of performing at their rated levels. Any corrective maintenance to the vehicle should be performed prior to commencement of testing, in addition to EAAK be added to the vehicle. AVTB is to then weigh and determine LCG for the vehicle. The suspension contractor will then provide new pressure settings for the suspension units.

As part of the LTI, it is requested that inspection of the return roller assemblies be conducted, including disassembly and inspection of bearing, seals, etc. Inspection procedures, and determination of replacement of parts should be in accordance with Bradley IFV procedures. At this time, 15-40W oil should be used for oil cavity re-fill in the support rollers.

3.0 - TEST ADMINISTRATION

3.1 Test Constraints:

This vehicle shall be operated in a manner consistent with the safe operating practices for all AVTB tracked vehicles. Safety guidelines will be those established by Chief-AVTB. It is at the discretion of AVTB to recommend that the baseline/chase vehicle to be used be outfitted with new suspension components (at AVTB's discretion) prior to testing so as not to bias test results.

3.2 Training and Familiarization of Personnel:

Through prior operation and testing of the LVTPX-12 with the new suspension system, no additional familiarization and training shall be required.

3.3 Detailed Test Requirements:

The following types of testing are to be conducted and test data accumulated on the AAV/HSS at AVTB:

- Ride Quality
- Cross Country Test Course
- Amphibious Compatibility
- Vehicle Handling Comparison
- Baseline Vehicle Requirements
- Design Requirements
- RAM-D Tests (500 miles)
- Towing Test

Each of these tests will be discussed in further detail in the following sections.

3.3.1 Ride Quality

Background

The ability of a tracked combat vehicle to transit cross country terrain without degrading embarked troop performance is paramount to the mobility and survivability of the FMF.

Purpose

Testing of this system parameter shall provide a quantification of the ride quality that this system possess versus a conventional AAV with a torsion bar/shock absorber suspension system.

Method

A test matrix should be established to measure Input Power Levels taken for the following variations in vehicle configuration:

a. Measurements taken on the modified AAV/HSS versus baseline AAV7A1
b. Measurements taken at Troop Compartment floor and Driver's Position
c. Measurements for vehicle weight conditions A & B
(discussion of weight conditions is presented in Appendix A)

Over a set terrain profile to be established at AVTB, the different test configurations will be run with the dual accelerometer data being recorded of input power levels. The vehicles shall enter and maintain pre-determined speeds in the test profile. Each test duration shall be of 2 minutes or less.

Data to be Reported

Test instrumentation will be the responsibility of AVTB, prepared and operated, and data reduction performed in accordance with standard procedures followed by the US ARMY for ride data. Gathered data shall compare ride quality of the modified vehicle versus the baseline vehicle (at different weight conditions) and shall be analyzed pursuant to MIL-STD-1472B for vibration levels and Army ride criteria for power absorption. Additional information on this test instrumentation is provided in Appendix B.

3.3.2 Cross Country Test Course Transit Time

Background

The survivability and mobility of a tracked combat vehicle is dependent on its ability to transit cross country terrain in the shortest possible time, within the human and vehicle limits of absorbing terrain induced loads.

Purpose

This test shall provide data on the time required and comparability of different suspension equipped vehicles to transit cross country terrain, allowing the vehicle driver's endurance and tolerance limits to dictate speed and time required for transitting the course.

Method

The modified and baseline vehicles shall be operated over a cross country test course established at AVTB. Minimum time required to transit the course shall be recorded for each vehicle. Interim times shall be measured through sections of the course dependent on terrain to be crossed (sandy, hill climb/descend, washboard, etc.).

Two vehicles shall be used: a baseline AAV (with no other suspension test components) and the AAV/HSS. Two vehicle crews (total for four different drivers) shall be utilized, taking turns driving each vehicle, twice in each direction, through the test course. The drivers shall operate the vehicles at safest maximum possible speed.

Tests should be conducted for weight conditions A & B.

No other test instrumentation is required.

Data to be reported

Times required for course completion.

Interim times for sections of the course.

Description of test course.

3.3.3 Amphibious Compatibility

Background

Force projection and amphibious deployments are required attributes for USMC tracked amphibious vehicles. All systems utilized on this type vehicle must be compatible with amphibious shipping and surf operations.

Purpose

The ability to embark and disembark amphibious shipping shall be demonstrated to validate compatibility with normal vehicle operations. Secondly, the vehicle must able to operate within and transit the surf zone.

Method

In conjunction with other AAV amphibious ship operations, the AAV/HSS shall embark and disembark amphibious ships when the opportunity is made available.

The vehicle shall be tested at weight conditions A and B. Weight condition A is the first test priority.

It shall be attempted to embark and disembark the ship at each weight condition three times.

The vehicle shall be operated, parked and secured in different ship areas to evaluate compatibility and safety concerns, including "dogging down" of vehicles for the duration of a Fire Watch period.

The vehicle shall be water towed and recovered (with track intact) onto amphibious shipping.

The vehicle should be operated in the surf zone (to safe and maximum extent possible, high surf desired) in conjunction and commensurate with other AAV surf operations.

Data to be reported

Video documentation of amphibious event (launch, recover, etc.).

Recording of number of attempts and successful missions.

Comments on any problems encountered boarding, launching, or while on ship. Comments on surf operation and handling.

Record environmental conditions (including well deck data).

3.3.4 Vehicle Handling Comparison Tests

Background

All changes and improvements to the AAV family must be done so without sacrificing or degrading current vehicle performance.

Purpose

Comparative testing of the operation and handling qualities of this modified vehicle versus a standard AAV shall be performed. Measurements required will be qualitative and quantitative.

Method

The following tests shall be performed with the vehicle in weight condition A and video coverage shall document vehicle operations:

(1) Accelerate the vehicle from 0-30 mph on a hard surface
(2) Decelerate the vehicle, in a panic stop mode, from 30 mph to a stop on a hard surface
(3) Operate the vehicle through a slalom course that provides 0.3g, 0.5g, and 0.7g turns at 10, 20, and 30 mph on a packed dirt/hard surface
(4) Operate the vehicle in the boat basin adjacent to AVTB and in the surf zone of Camp Pendleton beaches with waves up to 6 feet high

All of the above conditions shall be repeated at weight condition B.

Equivalent testing shall be performed with the baseline AAV7A1 at equivalent weight conditions.

Data to be reported

Recording of time required to accelerate/decelerate the vehicle should be performed with either stopwatches and/or strip chart recorders attached to the vehicle speedometers. Any instrumentation required to validate lateral acceleration and turn rate need not be reported, but only used to validate the test parameters. Top vehicle speed on a hard surface and in the water shall be recorded.

The only other measurements will be video documentation of vehicle operation of the modified AAV and baseline AAV during testing. To be watched for are unsafe operating conditions, or excessive pitch and roll movements during the maneuvers. Inability of either vehicle to safely perform the test should be documented.

The test condition of 0.7 g's at 10 mph shall be omitted. Comments on vehicle testing and handling should be recorded.

3.3.5 Baseline Vehicle Requirements

Background

New improvements and changes must not prevent the vehicle from performing to its original design specifications.

This series of testing will validate that the AAV/HSS vehicle still meets the baseline requirements of the AAV7A1, as detailed in the Developmental Testing III (DT-III) Test Requirements.

3.3.5.a - Trench Crossing Test

Purpose

To demonstrate that the test vehicle can cross a trench up to four feet deep and eight feet wide.

Method

(1) Place the test vehicle in weight condition A.

(2) Slowly drive the test vehicle over the required eight foot wide and four foot deep trench.

(3) Document the test with video or still photography, as appropriate.

(4) Repeat for vehicle weight condition B.

(5) Repeat for baseline AAV7A1 at equivalent weights.

Data to be reported

(1) Photographic and video documentation

(2) Trench dimensions

(3) Note and record any discrepancies, malfunctions, or problems.

3.3.5.b - Vertical Obstacle Test

Purpose

To demonstrate that the test vehicle can scale a 36-inch vertical obstacle

Method

(1) Place the test vehicle in weight condition A.

(2) Slowly drive the vehicle over the required 36-inch vertical obstacle.

(3) Document the test with video or still photography as appropriate.

(4) Repeat for vehicle weight condition B.

(5) Repeat for baseline AAV7A1 at equivalent weights

Data to be reported

(1) Video and Photographic documentation

(2) Obstacle dimensions

(3) Note and record any discrepancies, malfunctions, or problems.

3.3.5.c - Corrosion

Purpose

To determine any areas of the test items that are susceptible to corrosion.

Method

During testing, observe, analyze, and record suspension failures suspected of being due to corrosion. Observe and report any areas suffering corrosion effects.

Data to be reported

Record and report all suspension system failures due to corrosion in accordance with other failure reporting.

Make recommendations based on failure analysis and vehicle experience.

3.3.5.d - Climatic Testing

Purpose

To identify any aspects of the test items (or test vehicle installation) that are susceptible to improper operation during extremes in ambient operating temperatures.

Method

It is recommended that the vehicle and operation/maintenance crew be deployed to test regions where 500 miles of hot desert testing (100° - 125° F) and 500 miles of arctic testing (-25° - 0° F) can be accumulated sometime during the time period. During testing, observe, analyze, and record suspension failures suspected of being due to the environment. Observe and report any operational aspects suffering environmental effects. Conduct of baseline testing shall be accomplished to the maximum extent possible.

During this testing, vehicle weight should be varied among weight conditions A & B for the recommended percentages of operating time. Any adverse or beneficial impacts to vehicle performance as a result of weight changes should be noted.

Data to be reported

Record and report all suspension system failures and problems due to environmental effects in accordance with other failure reporting.

Make recommendations based on failure analysis and vehicle experience.

3.3.5.e - Slope Negotiation

Purpose

To determine the ability of the test vehicle to negotiate and maneuver on forward and side slopes safely.

Method

(1) Place the test vehicle in weight condition A.

(2a) Operate the vehicle on forward slopes up to and including 60% inclines. The vehicle should be operated in forward and reverse.

(2b) Operate the vehicle on side slopes up to and including 40% inclines.

(3) Document the test with video or still photography as appropriate.

(4) Repeat for vehicle weight condition B.

(5) Repeat for baseline AAV7A1 at equivalent weights.

Data to be reported

(1) Video and Photographic documentation

(2) Slope inclinations

(3) Note and record any discrepancies, malfunctions, or problems.

3.3.5.f - Pivot Steering

Purpose

To determine the ability of the test vehicle to pivot steer during land operations, as currently capability exists on the AAV7A1.

Method

(1) Inspect and adjust the HS-400-3 transmission for full pivot steer capability.

(2) Pivot steer the vehicle on varied terrains (hard surface, secondary roads, packed sand, vegetated terrain) during the course of vehicle operations and RAM-D mileage accumulation. The vehicle should be steered left and right at various speeds at the two weight settings.

(3) Document the test with video or still photography, as appropriate.

Data to be reported

(1) Video and Photographic documentation

(2) Vehicle rotation rates.

(3) Note and record any discrepancies, malfunctions, or problems.

3.3.5.g - Mine Plow Evaluation

Purpose

With future introduction and fitting of the mine plow to AAV's, this large weight mass at the nose of the vehicle and the push loads to be transmitted to the suspension system need to be investigated. This test is not to be an all-inclusive test, but a first look at identifying possible interface and operational problems.

Method

Following sufficient testing of the mine plow on a baseline AAV7A1, the plow shall be installed on the AAV/HSS. This shall be performed for a vehicle weight condition of 6000 pounds of cargo in the troop compartment.

(1) The vehicle with mine plow and 6000 pound cargo load shall be weighed and the LCG determined.

(2) The suspension contractor may provide new suspension unit pressures for this vehicle configuration to retain acceptable ground clearance. The nitrogen charge levels may be adjusted with new pressure settings.

(3) The vehicle with mine plow shall be operated and terrain plowed to evaluate impact on the suspension system. *

Data to be Reported

To be determined. *

* Pending test of the mine plow on the baseline AAV7A1 and its impact on vehicle operation, this sub-test and its criteria will be updated at a later date to include test methods and data gathering.

3.3.5.h - Noise Measurement

Purpose

Utilization of new components on the vehicle need to be evaluated for determination of whether or not they add to the acoustic signature of the vehicle.

Method

In accordance with procedures performed by AVTB to measure internal and external noise levels of other add-ons to the AAV7A1, similar efforts shall be employed to measure the levels for the AAV/HSS vehicle configuration.

This shall be performed for weight conditions A and B, and for the four listed terrain types:

- Paved road
- Loose sand
- Pack sand
- Secondary road

Data to be Reported

Data shall be recorded and reported in accordance with AVTB procedures for internal and external noise evaluations.

3.3.6 Design Requirements

Background

All new systems for evaluation should be monitored to validate proper functioning. Ride height and hydraulic/nitrogen levels in the suspension units are paramount to proper functioning.

3.3.6.a - Fluid and Gas Level Check

Purpose

To determine that the nitrogen and hydraulic oil levels, and their fill ports, maintain their settings during all vehicle operating conditions.

Method

(1) Utilizing the Operations and Maintenance manual procedures, check to insure that nitrogen gas levels are properly set and maintaining their settings.

(2) For the first 2000 miles, check nitrogen levels to see if they were maintained after every 250 miles of operation.

(3) Thereafter, check nitrogen levels to see if they were maintained after every 500 miles of operation.

(4) Hydraulic fluid levels need not be checked unless seepage and/or leakage is noted.

(5) With all units properly set, methods and procedures should be determined for installation and charging of units without the use of blocks under the vehicle. This shall incorporate corrective values for different roadwheel stations and different weight conditions.

Data to be reported

(1) Maintain a list of when each suspension unit required service or filling.

(2) Note and report discrepancies and malfunctions on appropriate maintenance and vehicle record logs.

(3) Tentative procedures for on-vehicle charging without use of support blocks.

3.3.6.b - Ride Height

Purpose

To determine whether the vehicle's height changes appreciably with time or temperature.

Method

(1) Utilizing the Operations and Maintenance manual procedures, measure vehicle height at the four corners of the vehicle hull at the following increments:

- Every 250 miles of operation
- Every two calendar months of operation
- At every ten degrees change in ambient temperature (when available and when testing at elevated/cold temperatures)

(2) Utilizing the weapon station sight or an inclinometer, measure vehicle attitude change (with time) after operational shutdown. This shall be performed to investigate effects on UGWS range card readings and system accuracy.

Data to be reported

(1) Maintain a list of height measurements when readings are taken and vehicle weight at the time.

(2) Note attitude changes with time and its effect on weapon station pointing accuracy.

(3) Note and report discrepancies and malfunctions on appropriate maintenance and vehicle record logs.

(4) Measurements should be made of baseline AAV7A1's at equivalent weights and LCG.

3.3.6.c - Return Roller Wear

Purpose

To observe wear rate and deterioration of return rollers during testing.

Method

AVTB operations and maintenance personnel shall monitor and report on abnormal wear and replacement of return roller components. This shall include development and implementation of any test procedures to measure damage and determine replacement guidelines.

Data to be reported

(1) Maintain a list of when support roller components required service and/or replacement.

(2) Note and report discrepancies and malfunctions on appropriate maintenance and vehicle record logs.

* During the course of vehicle testing, DTRC will provide to AVTB four new return rollers that utilize polyurethane tires and wear rings. Upon the removal of damaged rubber tire rollers, these new rollers should be installed until expended.

3.3.6.d - Roadwheel / Suspension Unit Interference

Purpose

To observe wear rate and deterioration that may result to roadwheel and/or suspension units as a result of interference between the components or as a result of terrain induced damage.

Method

AVTB operations and maintenance personnel shall monitor and report on abnormal wear and replacement of suspension units and roadwheels as a result of interference between the components or as a result of terrain induced damage. This shall include development and implementation of any test procedures to measure damage and determine replacement guidelines.

Data to be reported

(1) Maintain a list of when damage or interference required service and/or replacement.

(2) Note and report discrepancies and malfunctions on appropriate maintenance and vehicle record logs.

3.3.6.e - Track Tension Setting and Adjustment

Purpose

To observe track tension, its affect on vehicle operation, and determine applicable setting and measurement guidance. This is required as a result of the support roller interface and the affect on track tension and proper setting.

Method

AVTB operations and maintenance personnel shall monitor and report on abnormal wear and replacement of track components as a result of interference between the track and suspension components or as a result of terrain induced damage. This shall include development and implementation of any procedures to determine and set proper track tension.

AVTB shall experiment with and provide comments on ways to install and remove the track on the vehicle in various configurations and weights. This shall include estimates of crew levels, time required, numbers of personnel required and the need to remove EAAK panels (if necessary) for service to the track.

Data to be reported

(1) Maintain a list of track damage or interference that required service and/or replacement.

(2) Note and report discrepancies and malfunctions on appropriate maintenance and vehicle record logs.

(3) Times required, crew levels/quantity, and vehicle impact to service the track.

3.3.6.f - Installation and removal of suspension units

Purpose

To assess crew workload, level of difficulty, and anticipated maintenance burdens for this system that would be required for installation of units on the vehicle.

Method

AVTB operations and maintenance personnel (at various maintenance levels) shall perform suspension unit installation and removal in various configurations that could be anticipated by the FMF. This shall include, but not be limited to:

- Installation/removal while pressurized and unpressurized
- Installation/removal with and without hub attached
- Installation/removal at stations 1, 3, 6 - port and starboard
- Various lifting harnesses and lifting methods
- Different vehicle weights

AVTB shall experiment with (in matrix format) and provide comments on possibilities for accomplishing the above efforts, and provide feedback on what changes should be considered for future vehicle configurations to facilitate easier installation and removal of units.

Data to be reported

(1) Photographic coverage when deemed appropriate.

(2) Operator and maintenance personnel feedback on efforts undertaken and success of different methods.

(3) AVTB shall provide user feedback on lifting devices (either new or modified hardware currently available) to make this function easier and safer.

3.3.6.g - Short tracking of suspension units

Purpose

To assess crew workload, level of difficulty, and anticipated maintenance burdens for this system to be required for short tracking the vehicle in a field environment.

Method

AVTB operations and maintenance personnel (at various maintenance levels) shall experiment with and perform short tracking of the vehicle in various configurations that could be anticipated by the FMF. This shall include, but not be limited to:

- Installation/removal of units to facilitate short tracking
- Deactivation and tieing up of units during short tracking
- Impact on being towed when short tracked (using tow bars and cables)
- Removal of roadwheels and hubs
- Different vehicle weights
- Progressive increase and maximum number of roadwheel stations that can be deactivated (rear units, front units, mixed units)

AVTB shall experiment with (in matrix format) and provide comments on possibilities for accomplishing the above efforts, and provide feedback on what changes should be considered for future vehicle configurations to facilitate easier short tracking.

Data to be reported

(1) Photographic coverage when deemed appropriate.

(2) Operator and maintenance personnel feedback on efforts undertaken and success of different methods.

(3) Ground clearance changes.

3.3.7 Reliability, Availability, Maintainability and Durability

Background

New vehicle hardware must not provide a logistics and maintenance burden for the sake of improved performance. Reliability and maintainability must be documented and validated to evaluate the new systems benefits.

Purpose

To determine the test item's anticipated RAM-D characteristics during the test period.

Method

(1) Operate the test vehicle as outlined in paragraph 2.1. Maintain the vehicle and suspension system as outlined in the appropriate technical manuals.

(2) Perform all crew level maintenance actions required during the test operations and report in accordance with standard procedures.

Data to be reported

(1) Record all failures

(2) Record suspension maintenance data in accordance with appropriate procedures.

(3) Record and make note of any crew level special skills, tools, and procedures required for maintenance and operation of the suspension units and vehicle system not previously addressed in either vehicle manuals or those documents referenced in Appendix B.

(4) AVTB shall provide user feedback on the charging cart configuration, uses, and possible improvements to make this special tool easier to handle, use, and transport in future suspension applications. This feedback is also requested for any crew level special tools and procedures required to operate and maintain the suspension system.

3.3.8 Towing Tests

Background

All changes and improvements to the AAV family must be done without sacrificing or degrading current vehicle performance and capabilities.

Purpose

Comparative testing of the operation and handling qualities of this modified vehicle versus a standard AAV shall be performed when towing various items. Measurements required will be qualitative and quantitative.

Method

A test matrix shall be established and the following towing tests shall be performed with the vehicle in weight conditions A & B. Video coverage shall document vehicle operations.

1. Towing shall be conducted over the following terrains:

   - loose and packed sand
   - secondary roads
   - paved roads
   - cross country terrain.
   - mud/clay
   - vegetated

2. Towing shall be conducted (using bars and cables) with the following items towed by the AAV/HSS:

   - AAV of equal or less weight
   - M198 155 mm towed artillery
   - Standard trailer
   - Trailer mounted line charge
   - Other equipment deemed appropriate by AVTB

3. A baseline AAV at equivalent weight shall tow the AAV/HSS.

Data to be reported

Excessive loss of roadwheel travel shall be measured and documented. The only other measurements will be video documentation of vehicle operation of the modified AAV and baseline AAV during testing. To be watched for are unsafe operating conditions, or excessive vehicle movements during operation. Inability of either vehicle to safely perform the test should be documented.

3.4 Data Requirements and Instrumentation

At AVTB's recommendation, AVTB shall be responsible for ride quality instrumentation, data gathering, and data analysis. Two measurement devices should be installed in the test vehicles, measuring absorbed power/vibration levels at both the troop level and drivers seat simultaneously for comparison purposed. The vehicles should be run through the test profile as discussed in Section 3.3.1. The AAV/HSS and the AAV7A1 shall be run through the test profile one after another. This will be repeated for the two vehicle weight conditions. Discussion of US ARMY measurement techniques are presented in Appendix B.

For ride quality data, the baseline comparative value tc which testing should be run is a 0.7 inch RMS terrain. The required performance that the M1A1 tank tests against is sustained 29 mph speed over the 0.7 inch RMS terrain with 6.0 watts power absorbed at the drivers seat. If speed can be maintained through the terrain, then power absorption is to be measured. If speed can not be maintained, then maximum speed at the 6.0 watts level or less should be recorded.

All other instrumentation and data reduction that AVTB feels may be needed for the conduct of tests in this test plan will be the responsibility of AVTB, with data in analyzed form to be presented to DTRC at the conclusion of testing.

Vehicle operation is to occur on both land and in the water. AVTB will be responsible for structuring of tests and determination of how test should be conducted. AVTB will be responsible for utilizing applicable test procedures from previous or similar testing and for developing any new test plans and procedures.

3.5 Data Analysis, Documentation, and Reporting

It is requested that a vehicle log be maintained for observations and measurements taken pertaining to this system and series of tests.

It is requested that AVTB provide photographic coverage on sequences of AAV/HSS testing. During testing, video coverage representative of testing being conducting is requested in accordance with Section 3.3 of this test plan.

Color still photographs should also document testing, along with any ancmalies encountered or failures that may occur to hardware during testing.

It will be at the discretion of the AVTB Operations Office to request photographic coverage.

The accumulation reliability information is for informational purposes and to track trends/deficiencies, vice tabulation of classical RAM-D data.

AVTB shall continue to include the status of the vehicle testing in their monthly reports.

AVTB shall prepare and distribute Test Incident Reports (TIR) for abnormal events and failures. These reports shall be distributed to AVTB, DRPM AAA, DTRC, and CGT with a recommended tasking for action. These reports should be developed and maintained for the whole test program and should be distributed as soon as reasonably possible.

Provided in Appendix C is a vehicle operator's questionnaire. It is requested that all crew members that drive, maintain, or are involved in the testing of the AAV/HSS be given copies of and complete this questionnaire after discrete test point completion.

At the conclusion of testing, it is requested that AVTB prepare and forward compiled test results, findings, and comments in the form of a Final Report to DTRC and DRPM AAA. This report shall describe:

- Test Data
- List of tests attempted/achieved
- Narrative discussion of test results
- Completed questionnaires

3.6 Logistics Support during Testing

The LVTPX-12 test vehicle will be shipped to the test site by the contractor. Shipment will be by truck with drive on/drive off capability. Shipment of required test items and repair parts will coincide with delivery of the test vehicle. Only field serviceable repair parts will be delivered to AVTB. Depot repairable parts will be retained at the contractor's facility.

The maintenance of the LVTPX-12 vehicle will be the responsibility of AVTB, including all service and parts not unique to the hydropneumatic suspension system.

Spare parts unique to the suspension system and the vehicle installation will be provided with the test vehicle. A list was provided in reference (6) of Appendix B. This quantity of parts should support testing for at least one year. If additional parts or high usage parts are required, it will be the responsibility of AVTB to procure these parts. Any maintenance that will require disassembly of the suspension unit will be provided by the suspension contractor at his facility. With the delivery of the test vehicle will be two spare suspension units (one port, one starboard). Damaged suspension units or units in need of repair shall be shipped to the contractor for rework.

Maintenance procedures for required service checks of the hydropneumatic suspension units is provided in reference (1) of Appendix B.

APPENDIX A
VEHICLE TESTING WEIGHT CONDITIONS

The following vehicle configurations shall be tested for the AAV/HSS. Outfitting of the vehicle has been accomplished utilizing actual components with the exception of ballast for troop and cargo/LMC load. The below listed weights are actual measurements for the AAV/HSS vehicle.

	CONDITION	AAV/HSS WEIGHT (pounds)
A.	Combat Equipped, plus EAAK and Troops	53,500 pounds
B.	Combat Equipped, plus EAAK & 10,600 lbs. cargo (LMC kit)	58,100 pounds

The following is a tabulation of components attributed to the vehicle:

<u>WBS</u>	<u>Component</u>
1000	Hull, Welded & machined
1100	Bow Plane
2000	Powertrain
3000	Transmission
4000	Aux. Propulsion
5000	Suspension (HSS replacement for torsion bar system)
6000	Armament (UGWS, combat ready)
7000	Subsystems
8000	OEM/Comm equipment
9100	Crew of three
9200	Fuel (171 gallons)

LOADED ITEMS

WBS	Component
9300	LMC kit - Cargo (10,600 lbs)
9400	20 troops & 1 TC (@ 285 lbs ea)
9520	Enhanced AAK

APPENDIX B

DOCUMENTATION REFERENCES

1. "OPERATIONS AND MAINTENANCE MANUAL FOR HYDROPNEUMATIC SUSPENSION SYSTEM INSTALLED ON P-7 AMPHIBIOUS ASSAULT VEHICLE", document number AMS/721/M5-RB89303, published by Cadillac Gage-Textron on 5 October 1989.

2. "HUMAN VIBRATION RESPONSE MEASUREMENT", TACOM Technical Report 11551, dated June 1972
(DTIC # AD901195).

3. "DESIGN REPORT FOR AN IN-ARM HYDROPNEUMATIC SUSPENSION UNIT", published by Cadillac Gage-Textron, September 1988.

4. "FINAL REPORT FOR AN IN-ARM HYDROPNEUMATIC SUSPENSION UNIT", published by Cadillac Gage-Textron, date TBD.

5. "DETAILED TEST PLAN - DEVELOPMENT TEST III for the LANDING VEHICLE TRACKED MODEL 7A1 (LVT7A1)", published by MCDEC, September 1983.

6. "TEST PLAN FOR A HYDROPNEUMATIC SUSPENSION SYSTEM MOUNTED ON AN ASSAULT AMPHIBIAN VEHICLE (LVTPX-12)", prepared by the David Taylor Research Center, May 1990, Revision 4.

APPENDIX C

AAV/HSS OPERATOR'S QUESTIONNAIRE

1. Approximately how many hours experience have you had in driving the test vehicle?

2. Have you had experience driving the standard AAV7A1 vehicle? If so, approximately how much?

3. Do you consider the handling characteristics of the test vehicle to be adequate insofar as safety is concerned?

   If not, please elaborate.

4. Do you find the test vehicles hard to control over a certain terrain or in a particular situation? If so, please elaborate.

5. Do you find driving or riding in the test vehicle to be unusually tiring or the opposite, less tiring?

6. Do you have any comments (gathered from operating, maintaining, or riding in the test vehicle) which you consider appropriate to the suspension system, installation, or features?

APPENDIX I

VEHICLE WEIGHTS, CGs, AND GROUND CLEARANCES

TABLES OF WEIGHTS, LCG, AND GROUND CLEARANCE

PX12-10 WITH EAAK INSTALLED WEIGHT AND LCG WITH GROUND CLEARANCE

WEIGHT	47,500#
LCG	88-7/8"
VCG	27-1/4"

GRND CLR	PORT	STARBOARD
FORWARD	15"	15-1/4"
AFT	23-5/16"	23-1/2"

REMARKS: Not combat equipped.

WEIGHT	49,180#
LCG	86-3/4"
VCG	26-7/8"

GRND CLR	PORT	STARBOARD
FORWARD	13-3/4"	14"
AFT	21-1/4"	21-1/2"

REMARKS: Weighted to represent the combat equipped test criteria.

WEIGHT	55,540#
LCG	97-1/4"
VCG	22-7/8"

GRND CLR	PORT	STARBOARD
FORWARD	16-5/8"	16-1/4"
AFT	14-5/8"	14-1/16"

REMARKS: Weight is centered. Weighted to represent the troop loaded test criteria.

WEIGHT	55,540#
LCG	93-3/8"
VCG	29-5/16"

GRND CLR	PORT	STARBOARD
FORWARD	14"	13"
AFT	18"	17-1/4"

REMARKS: Weight is mounted forward. Weighted to represent the troop loaded test criteria.

WEIGHT	59,600#
LCG	99-1/2"
VCG	19-7/8"

GRND CLR	PORT	STARBOARD
FORWARD	15-3/8"	15-5/8"
AFT	12-3/8"	12"

REMARKS: Weights are centered. Weighted to represent the cargo loaded test criteria.

WEIGHT	59,600#
LCG	93-1/2"
VCG	21-1/2"

GRND CLR	PORT	STARBOARD
FORWARD	14-3/8"	13-1/2"
AFT	15-13/16"	15-1/8"

REMARKS: Weights were mounted forward. Weighted to represent the cargo loaded test criteria. Vehicle was test operated in the jetty and performed in a safe and satisfactory manor. This condition is safe for water operations.

APPENDIX J

FAILURE ANALYSIS REPORT

FAILURE ANALYSIS REPORT

BASIC DATA

TEST PROGRAM: 6K HSS EQUIPPED LVT PX - 12 VEHICLE

F/A REPORT NO.: 001

REPORT DATE: 20 AUGUST 1990

PROBLEM: LEAKING GAS SPRING SYSTEM

INCIDENT DATE: 24 JULY 1990

SUSPENSION UNIT S/N: 2

ROADARM STATION NO.: #2 LEFT

NARRATIVES

DESCRIPTION OF FAILURE:

SEE ATTACHED SHEET

ANALYSIS OF PROBLEM:

SEE ATTACHED SHEET

DESCRIPTIONS OF CORRECTIVE ACTIONS:

SEE ATTACHED SHEET

TEST RESULTS ON CORRECTIVE ACTIONS:

N/A

DESCRIPTION OF FAILURE:

A visual inspection of the vehicle revealed that the front of the vehicle was not at the proper ride height. The vehicle was put up on stands to check the gas spring charge pressures. The charge pressure in the left #2 unit was measured at 325 psi compared to a required 3200 psi. An attempt was made to recharge the suspension unit, however, it would not hold a charge. The suspension unit (S/N 2) was replaced with another unit (S/N 7) and returned to Cadillac Gage for failure analysis.

ANALYSIS OF PROBLEM:

A failure analysis was initiated to identify the cause of the gas spring pressure loss. Disassembly and inspection of the suspension unit identified the following problems, which are discussed in detail below:

1. Missing spindle rebound stop block.
2. Broken connecting bar.
3. Sand/rust build-up in the crankcase seal area.
4. Loose front cover retaining screws.

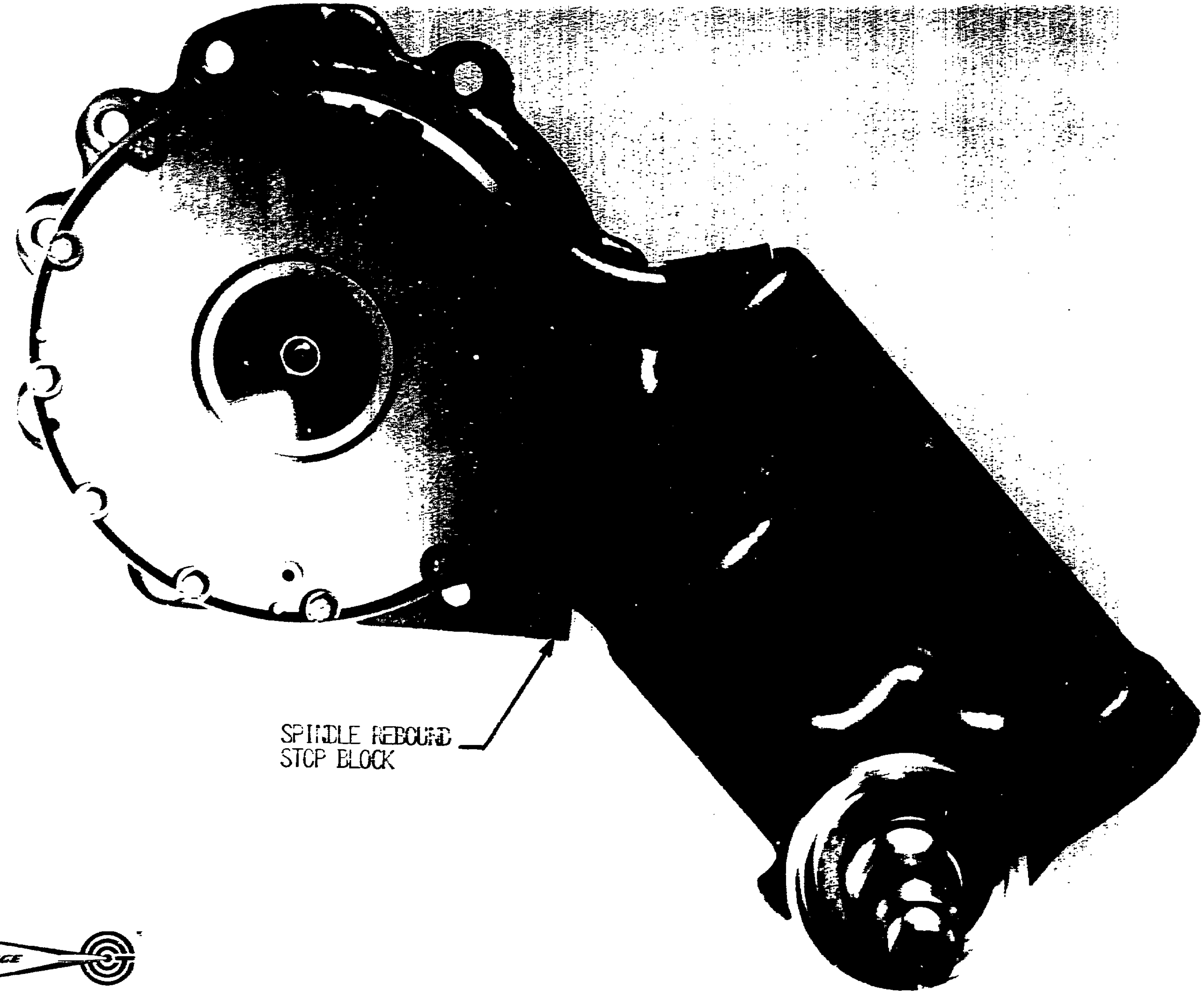
MISSING SPINDLE REBOUND STOP BLOCK:

The spindle rebound stop block (P/N AS700321) was found to be missing (See Figure 1). The stop block retaining screw and shear pin were sheared off at the stop block/spindle interface. This was caused by misalignment (non-square contact) of the roadarm and spindle mounted stop blocks during a rebound strike. The misalignment was probably caused by rocks or other debris becoming sandwiched between the stop blocks.

Operation of the suspension unit with a missing rebound stop block allowed the suspension unit to over-travel and bottom the connecting bar on the spindle (See Figure 2). Therefore, loss of the rebound stop block was the primary mode of failure which resulted in secondary failures of the connecting bar and ultimately the gas spring system.

BROKEN CONNECTING BAR:

Structural failure of the connecting bar was a secondary failure resulting from operation of the suspension unit with a missing rebound stop block. The connecting bar is a weldment which under normal operation is always loaded in compression. As the suspension unit over-travels, the connecting bar bottoms on the spindle, loading it in both shear and bending, causing the weld between the bar and ball to fracture (See Figure 3). Although the suspension unit continued to operate for some time after the connecting bar had broken, metal chips generated by the failure eventually scratched and scored the high pressure seals and



CADILLAC GAGE

FIGURE 1

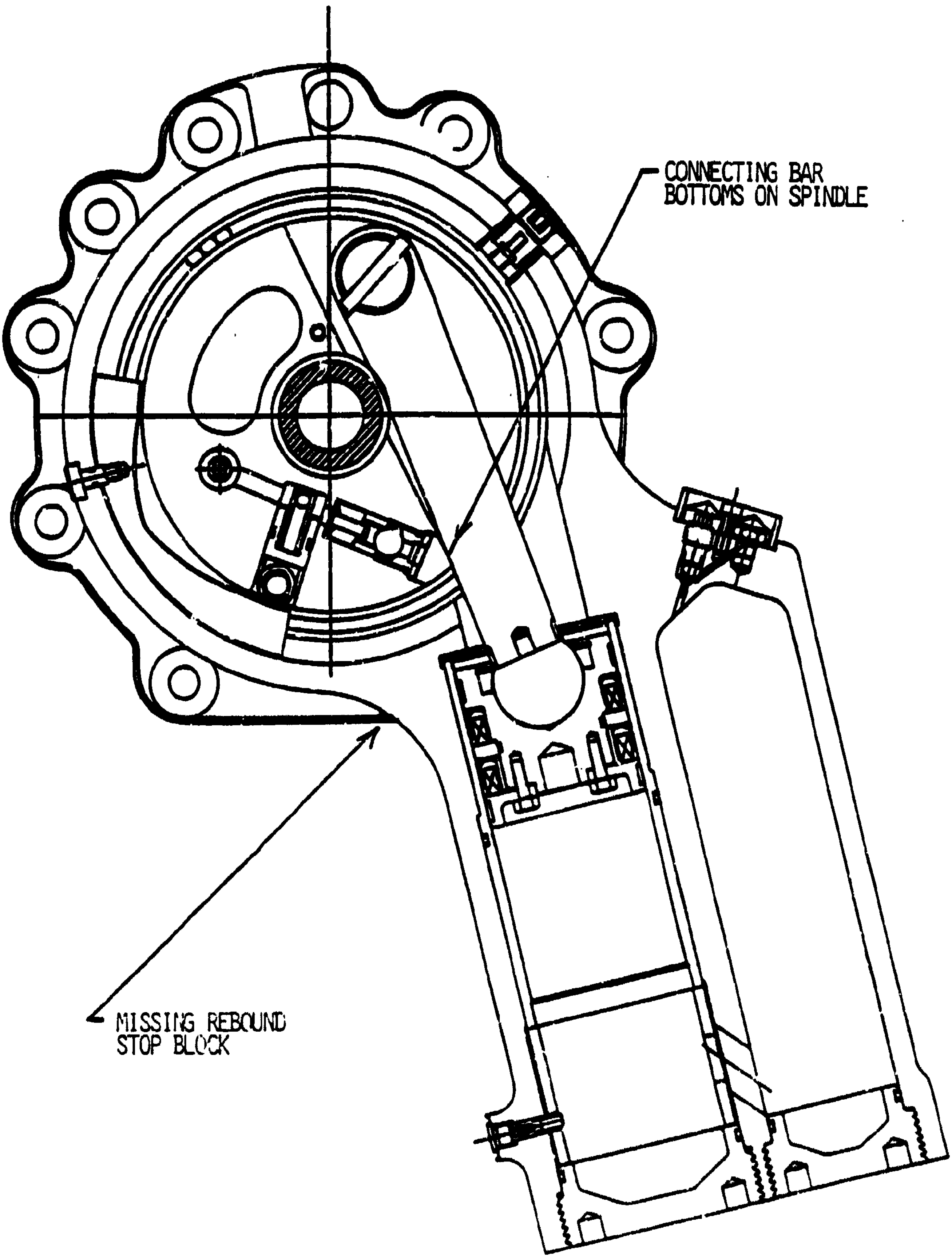

CONNECTING BAR
BOTTOMS ON SPINDLE
MISSING REBOUND
STOP BLOCK

FIGURE 2

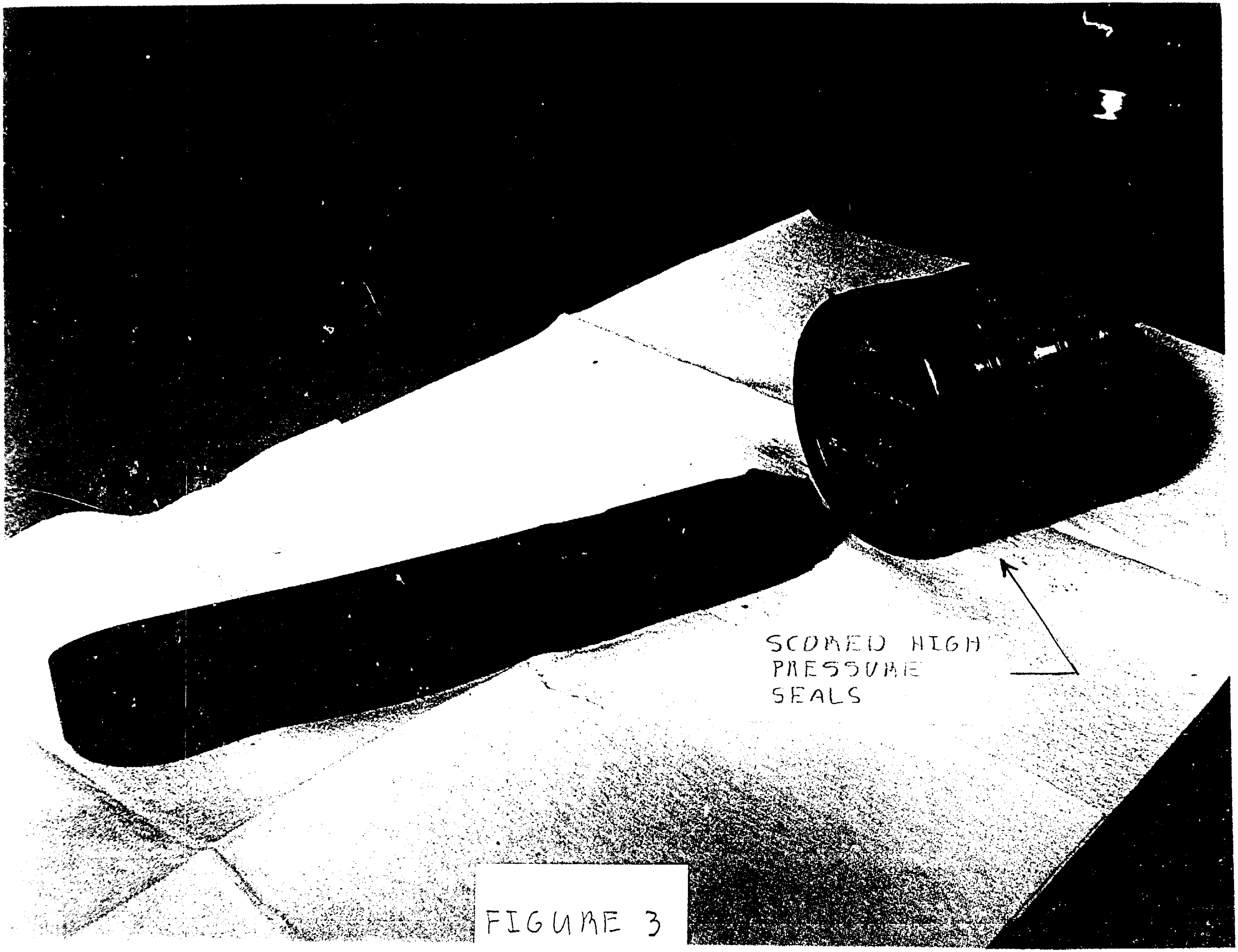


FIGURE 3

sleeve, resulting in the gas spring pressure loss.

SAND/RUST BUILD-UP IN THE CRANKCASE SEAL AREA:

During disassembly of the suspension unit, it was noted that a significant amount of sand and dirt was packed between the crankcase dust and oil seals. Also, the sealing surfaces for both seals were rusted and grooved (See Figure 4). These problems, which are accelerated by the saltwater/sand environment, would have eventually resulted in failure of the crankcase seal system (crankcase oil and gas leakage).

Failure of the crankcase seal system is a recognized design problem which progresses in the following manner:

1. Saltwater induces corrosion of the dust seals non-protected steel sealing surface.

2. Wear of the dust seal lip is accelerated as it runs over the rough rusted and pitted sealing surface.

3. The rough sealing surface allows sand and dirt to work its way under the sealing lip, causing additional wear and grooving of the relatively soft (Rc 36) steel sealing surface.

4. The dust seal becomes ineffective, allowing sand, dirt, and saltwater to pass through and accumulate under the crankcase oil seal.

5. The sand and dirt quickly abrade the soft crankcase oil seal, resulting in crankcase oil and gas leakage.

Cadillac Gage has redesigned the crankcase dust seal. Laboratory testing of the new dust seal configuration should be completed by the end of September. Upon successful lab testing of the new seals, the suspension units are to be removed from the vehicle and modified with the new dust seals.

LOOSE FRONT COVER RETAINING SCREWS:

The front cover retaining screws were checked to see if any had loosened. Three screws were found to be loose, and two were finger tight (See Figure 5). The locking tabs, installed to prevent the screws from loosening, were ineffective. They were bent and broken by debris trapped between the roadwheels and the front covers. Loosening of the front cover retaining screws is a recognized design problem which will require additional analysis and evaluation. This problem is to be resolved under a follow-on contract.

DESCRIPTION OF CORRECTIVE ACTIONS:

FIGURE 4

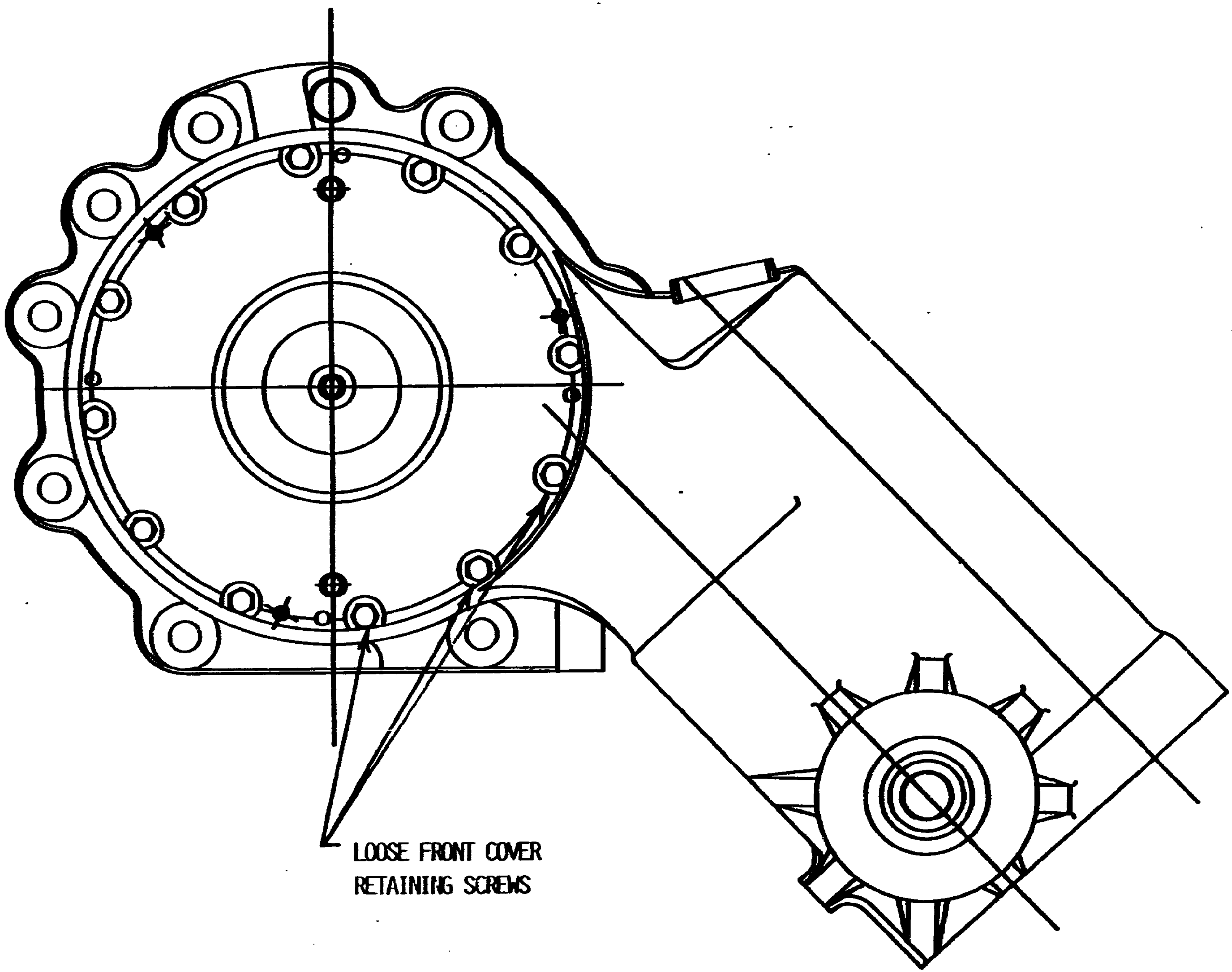


FIGURE 5

The suspension unit was refurbished and returned to Twenty-Nine Palms to be used as a spare. Refurbishment included the following:

1. Replacement of the complete spring system.

2. Installation of a new spindle rebound stop block.

3. The crankcase oil and dust seals were replaced.

4. The crankcase oil and dust seal diameters on the roadarm (See Figure 6) were machined to remove the rust and pits, and them chrome-plated to bring them back to size.

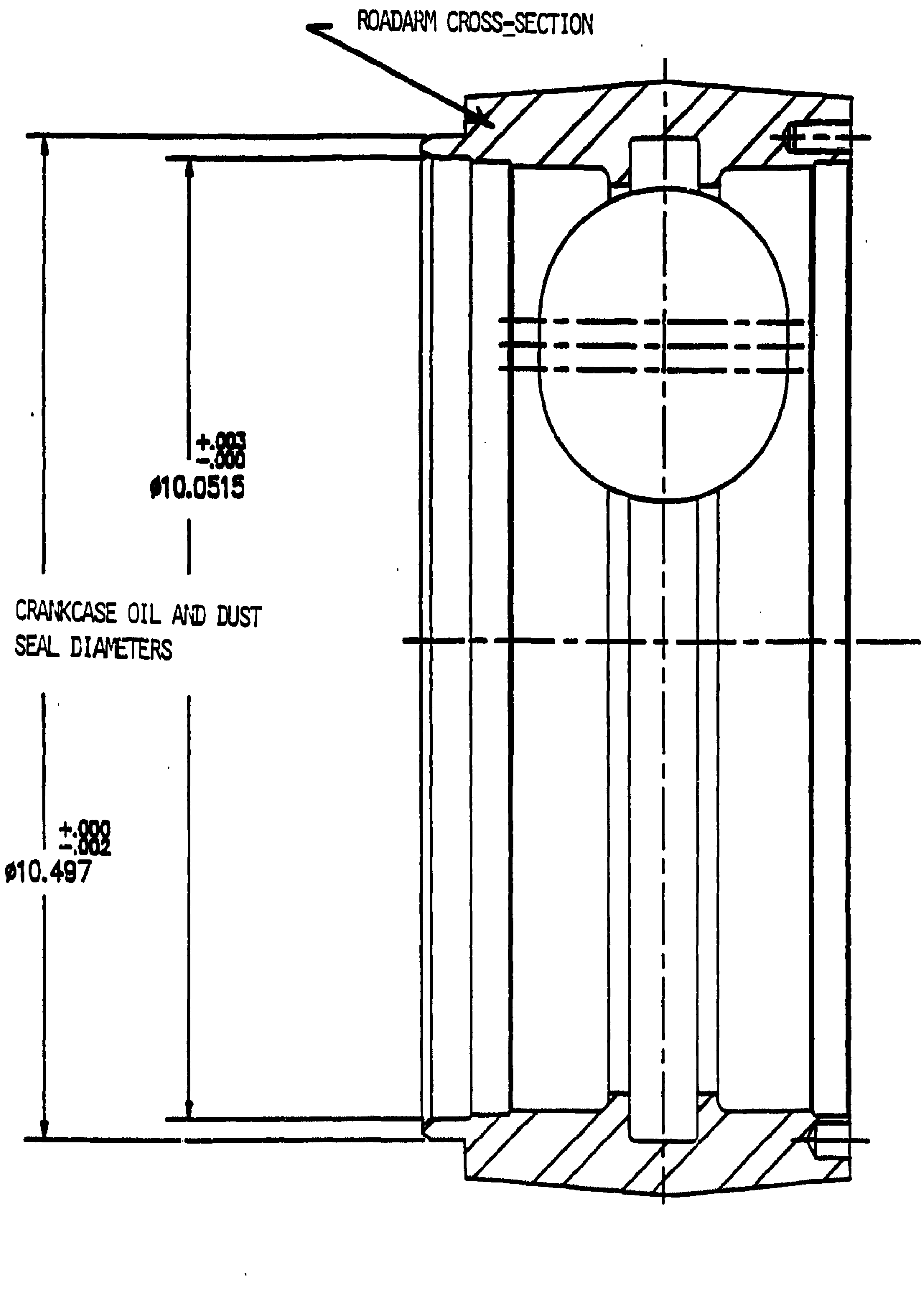

ROADARM CROSS-SECTION
+.003
−.000
ø10.0515
CRANKCASE OIL AND DUST
SEAL DIAMETERS
+.000
−.002
ø10.497

FIGURE 6

FAILURE ANALYSIS REPORT

BAISC DATA

TEST PROGRAM: 6K HSS EQUIPPED LVT PX - 12 VEHICLE

F/A REPORT NUMBER: 002

REPORT DATE: 24 AUGUST 1990

PROBLEM: LEAKING GAS SPRING SYSTEM

INCIDENT DATE: 25 JULY 1990

SUSPENSION UNIT S/N: 8

ROADARM STATION NUMBER: #1 RIGHT

NARRATIVES

DESCRIPTION OF FAILURE: SEE ATTACHED SHEET

ANALYSIS OF PROBLEM:

SEE ATTACHED SHEET

DESCRIPTIONS OF CORRECTIVE ACTIONS:

SEE ATTACHED SHEET

TEST RESULTS ON CORRECTIVE ACTIONS:

N/A

DESCRIPTION OF FAILURE:

Once the vehicle test weights and center of gravity locations were finalized by DTRC, Cadillac Gage calculated the optimum gas spring charge pressures to be 3200 psi at stations 1 and 2, and 1975 psi at stations 3 thru 6. While recharging the system to the newly specified pressures it was noted that the gas spring charge pressure in the number 1 right unit was 1515 psi compared to a required 3200 psi. The suspension unit was recharged to 3200 psi, however, the pressure would not stabilize indicating a leak. The suspension unit S/N 8 was replaced with S/N 11 and returned to Cadillac Gage for failure analysis.

ANALYSIS OF PROBLEM:

A failure analysis was initiated to identify the cause of the gas spring pressure leakage. Disassembly/inspection of the suspension unit identified the following problems:

1. Failure of the main cylinder bore end cap T-seal.

2. Sand/rust build-up in the crankcase seal area.

FAILURE OF THE MAIN CYLINDER BORE END CAP T-SEAL:

While removing the main cylinder bore end cap it was noted that the outboard T-seal back-up ring was out of position. It appeared as if, during assembly, the back-up ring hung up in the thread relief groove machined in the roadarm, partially pulling it from the seal groove in the end cap (See Figure 1). This in turn allowed the rubber portion of the T-seal to extrude into the gap between the end cap and roadarm bore (See Figure 2). As a result of the fluctuating pressures (movement of the roadarm) the rubber portion of the T-seal was extruded/nibbled away and eventually a leak path was formed for the gas spring charge (See Figure 3). Therefore, leakage of the gas spring charge was due to the failure of a improperly installed end cap T-seal.

SAND/RUST BUILD-UP IN THE CRANKCASE SEAL AREA:

During disassembly of the suspension unit it was noted that a significant amount of sand and dirt was packed between the crankcase "dust" and oil seals. Also, the sealing surfaces for both seals were rusted and grooved (See Figure 4).

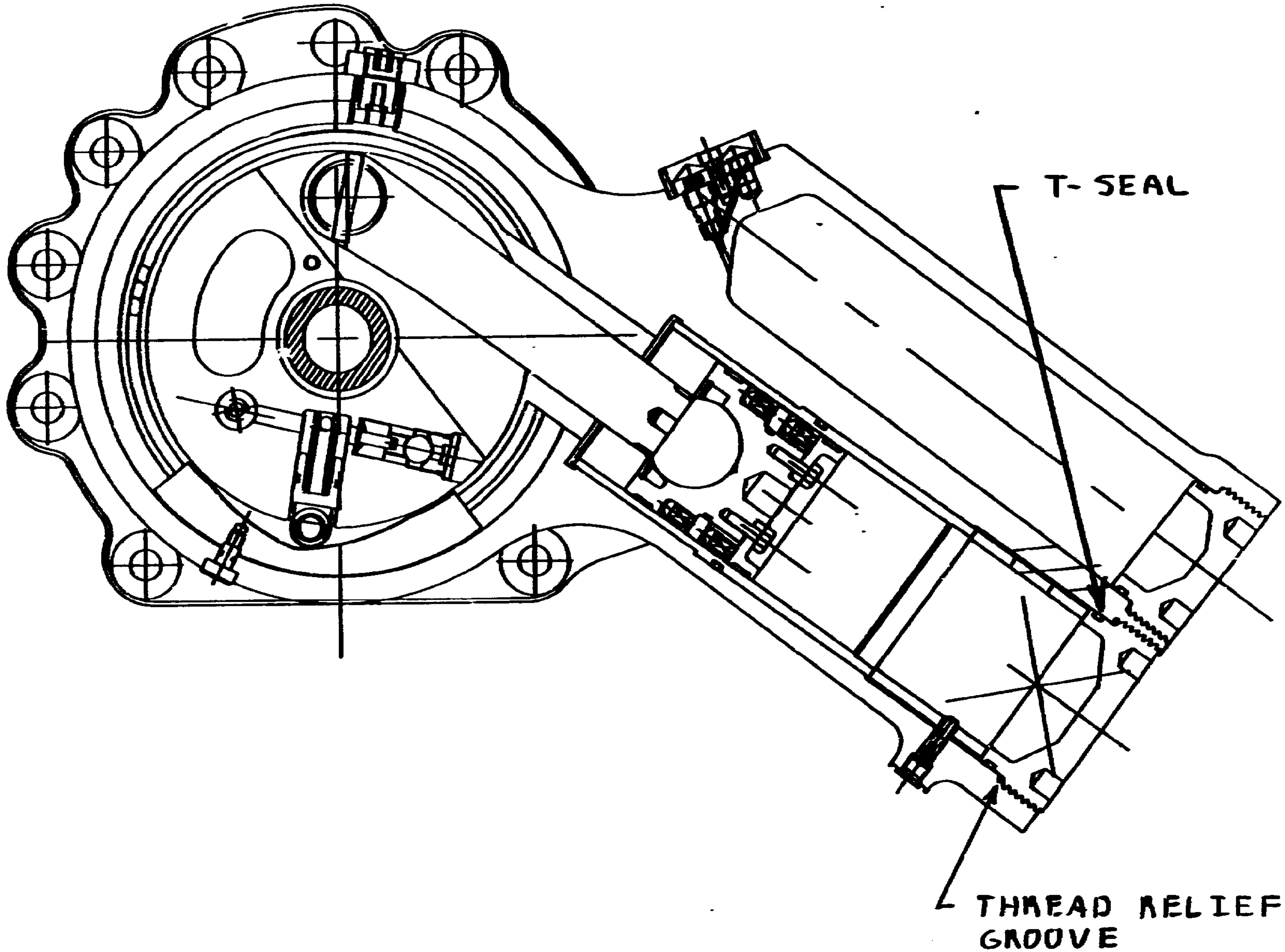
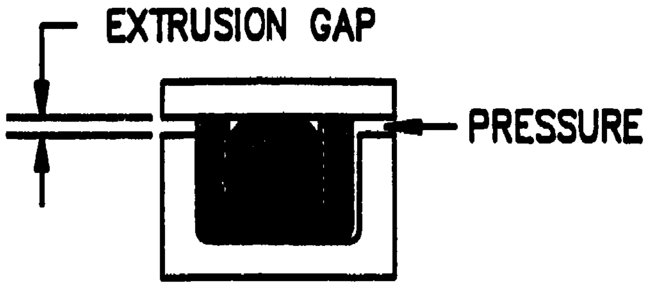
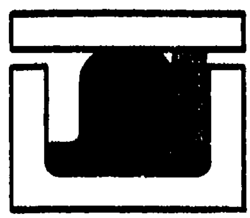


FIGURE 1

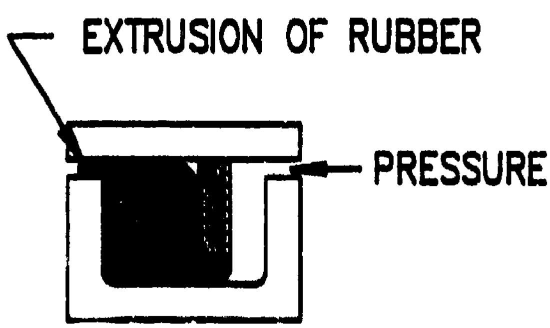
T-SEAL CROSS SECTIONS



NORMAL T-SEAL OPERATION



T-SEAL WITH OUTBOARD BACK-UP
RING PARTIALLY MISSING (STATIC, 0 PRESSURE)



T-SEAL WITH OUTBOARD BACK-UP
RING PARTIALLY MISSING (UNDER PRESSURE)

FIGURE 2

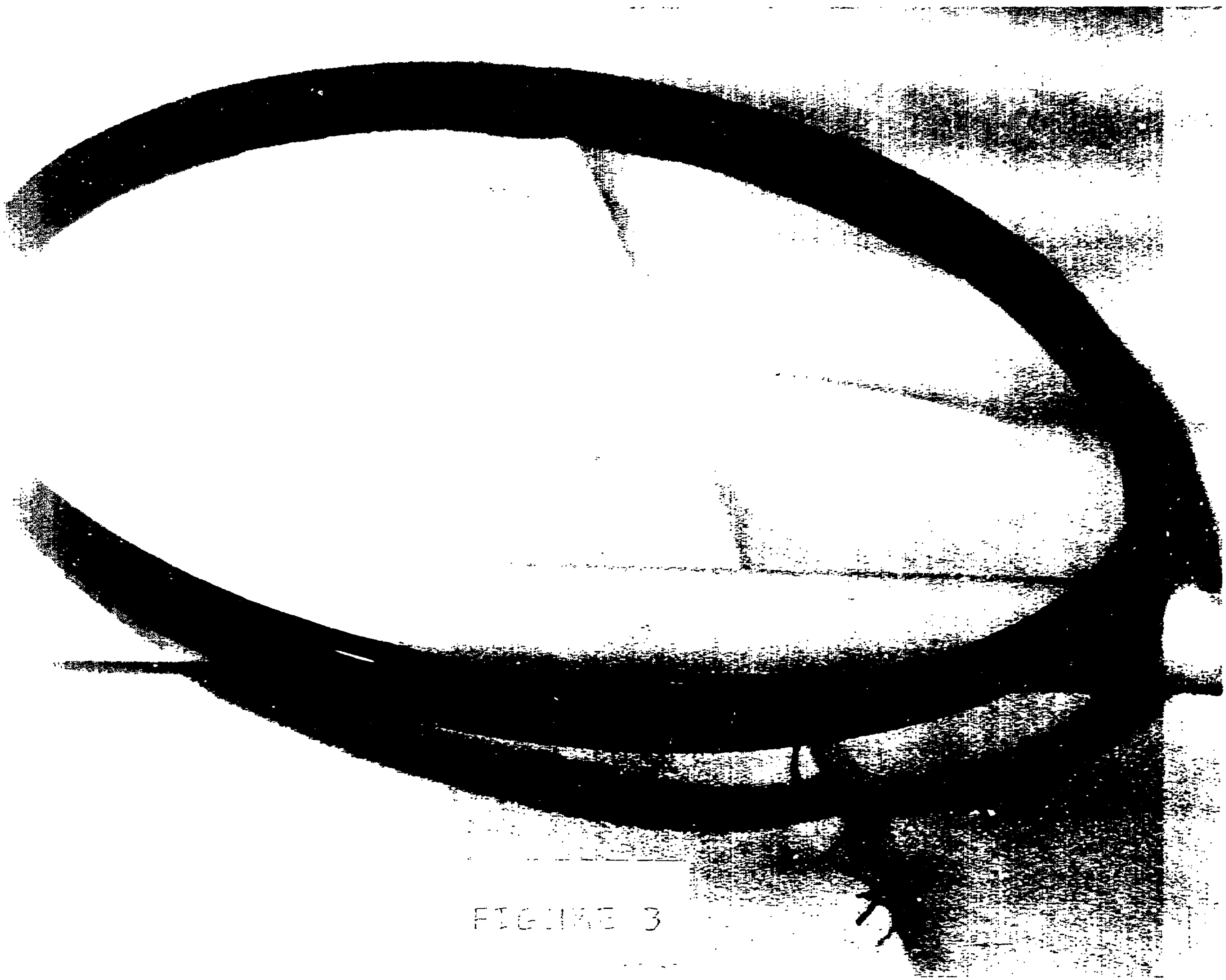


FIGURE 3

SAND/RUST BUILD-UP IN THE CRANKCASE SEAL AREA (CONT'D):

These problems, which are accelerated by the saltwater/sand environment would have eventually resulted in failure of the crankcase seal system (crankcase oil/gas leakage).

Failure of the crankcase seal system is a recognized design problem which progresses in the following manor:

1. Saltwater induces corrosion of the "dust" seals non-protected steel sealing surface.

2. Wear of the dust seal lip is accelerated as it runs over the rough rusted/pitted sealing surface.

3. The rough sealing surface allows sand/dirt to work its way under the sealing lip, causing additional wear and grooving the relatively soft (RC 36) steel sealing surface.

4. The "dust" seal becomes ineffective allowing sand, dirt and saltwater to pass and accumulate under the crankcase oil seal.

5. The sand/dirt quickly abraded the relatively soft crankcase oil seal resulting in crankcase oil/gas leakage.

Cadillac Gage has redesigned the crankcase "dust" seal. Laboratory testing of the new "dust" seal configuration should be completed by the end of September. Upon successful lab testing of the new seals, the suspension units are to be removed from the vehicle and modified with the new "dust" seals.

DESCRIPTION OF CORRECTIVE ACTIONS:

The suspension unit was refurbished and returned to 29 palms to be used as a spare. Refurbishment included the following:

1. Replaced the main bore end cap T-seal. All T-seals and O'rings are normally replaced as part of any unit refurbishment.

2. The crankcase oil and dust seals were replaced.

3. The crankcase oil and dust seal diameters on the roadarm (See Figure 5) were machined to remove the rust/pits and then chrome plated to bring them back to size.

A:PETE2

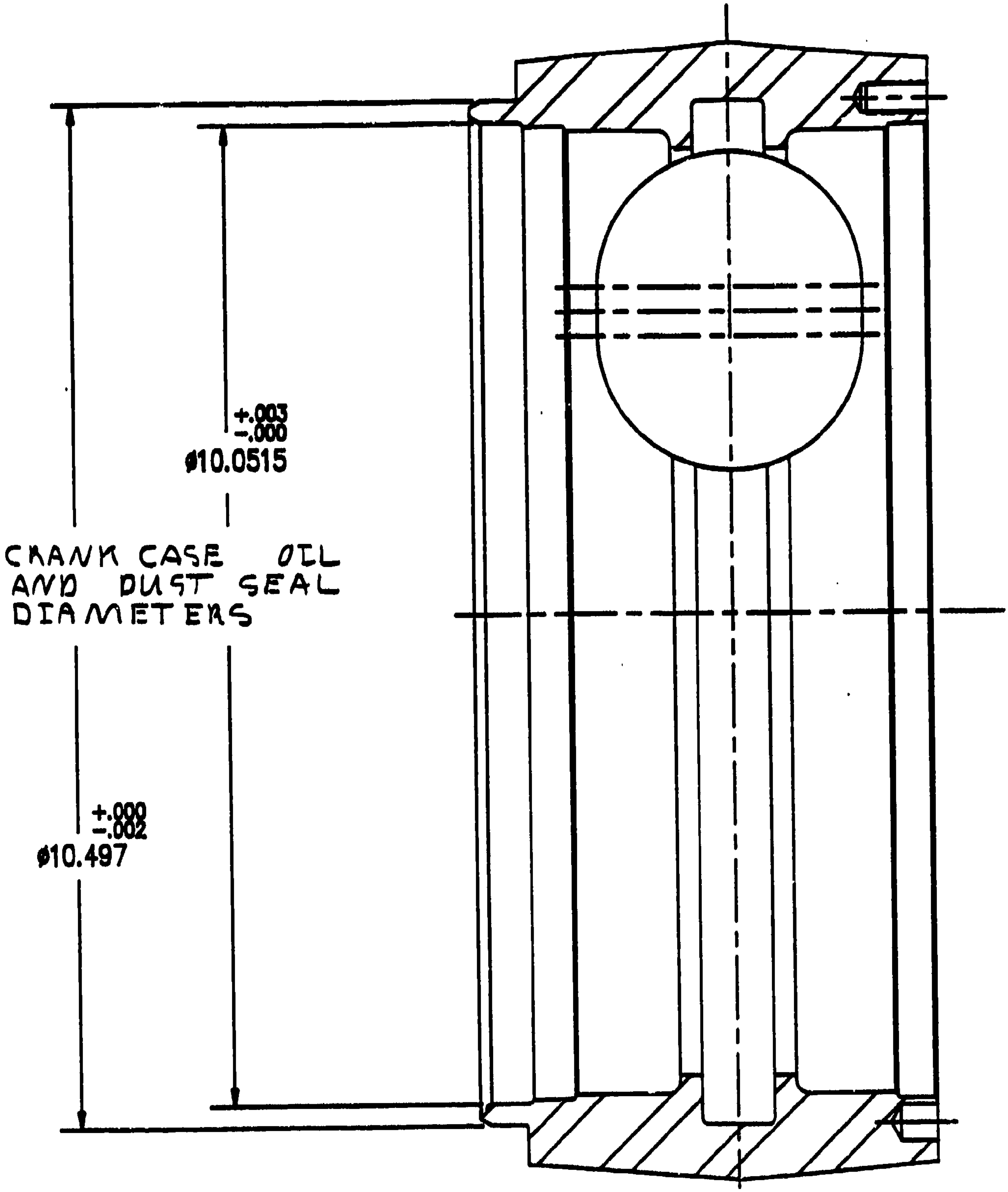

+.003
-.000
ø10.0515
CRANK CASE OIL
AND DUST SEAL
DIAMETERS
+.000
-.002
ø10.497

FIGURE 5

APPENDIX K

PRODUCTION COST STATEMENT (UNIT COST)

CDRL SEQUENCE NUMBER A012

DATA ITEM NUMBER DI-F-1212

COSTING INFORMATION IS

COMPETITION SENSITIVE

This information resides within

the Government and is controlled by DTRC.

Point of Contact is M. Gallagher,

Marine Corps Programs Office

(301) 227-1852

ADDENDUM

DESIGN REPORT

RETRACTABLE HYDROPNEUMATIC SUSPENSION SYSTEM

PROOF OF PRINCIPLE
FEBRUARY, 1991

CONTRACT NO. N00167-88-C-0024
AMENDMENT P0011

FOR

DAVID TAYLOR RESEARCH CENTER

PREPARED BY: ______________________ **DATE:** ____________

APPROVED BY: ______________________ **DATE:** ____________

CONTENTS

List of Illustrations

List of Enclosures

1.0 Scope

This report summarizes the effort and results of modifying a 6K hydropneumatic suspension unit to prove the feasibility of a retractable suspension unit for use on amphibious military tracked vehicles. Also included is a concept design for a fully retractable suspension system.

2.0 Objective

The objective of this contract amendment (#P0011) was threefold: 1) to prove the feasibility of retraction on a modified 6K hydropneumatic suspension unit, 2) to demonstrate the reliability of retraction, and 3) to provide a concept design of a fully retractable suspension system for use on tracked amphibian vehicles.

3.0 Program Plan

To verify the principle of retraction, a design was developed modifying a current 6K ISU to include the retraction feature. The purpose of this unit is for testing only and is not intended for vehicle installation. A brass board high pressure supply was fabricated using "off the shelf" components where possible. Although the brass board system simulates the vehicle control system in function, size and flow capabilities are not representative of those that would be used for vehicle operation.

The test unit was then cycled through the retraction operation while measurements of its characteristics were taken.

Concurrent with the testing effort, a concept design was developed for a retractable 6K hydropneumatic suspension system consisting of 6K retractable ISUs, track tensioner, and vehicle control system. A system weight analysis was also included.

4.0 System Design

4.1 Suspension Test Unit

4.1.1 Requirements

The initial design effort to duplicate the geometry and kinematics required for a vehicle installation, as outlined in Enclosure A, revealed that the condition exceeded the designed capabilities of the unit being modified. Due to the unit configuration and space limitations within the roadarm, the attempt to duplicate spring pressure needed for roadwheel loads resulted in excessive retraction pressure. This, in turn, exceeded the capabilities of the unit's internal components and roadarm.

As a result, the criteria was redefined for the test unit, specifically:

Jounce Position	12.5 inches vs 17.0 inches	
Rebound Travel	3.5 inches vs 5.0 inches	
Static Position	-9.379 inches vs -11.0 inches	
Jounce Load	18,000 lbs. vs 21,000 lbs.	
Roadarm Length	16.0 inches vs 18.0 inches	

This allowed the unit to be modified to a workable test specimen providing "Proof of Principle" for retraction. The geometry of the spring system is shown in Figure 1. Theoretical spring curve calculations, executed using the VEHDYN II program, can be found in Enclosure B.

4.1.2 Configuration

By redesigning the piston assembly and cylinder components, a retraction chamber was created between the damper crankcase and piston. The main end cap was modified to allow an internal flow path between the piston hydraulic cylinder and gas accumulator cylinder (see Figure 2).

When the retraction chamber is sufficiently pressurized, the load due to the hydropneumatic spring is overcome, and the suspension is retracted. The retraction pressure required thus becomes a function of the area ratio between the spring piston and retraction chamber. A plot of the two pressures versus position is shown in Figure 3.

Retraction fluid and pressure is supplied via an external connection to the roadarm. Although the connecting bar length was not revised, a new connecting bar was required to insure that the tension loads due to the retraction operations were managed.

The damper assembly and components were not altered and are those that were fabricated under the initial scope of this program.

4.1.3 Design Parameters - Test Unit

Assembly Drawing	LO-102890
Kinematics:	
Wheel Travel	-3.5 inches to 12.5 inches
Static Position	-9.379 inches
Rebound	-3.5 inches
Jounce	12.5 inches
Roadarm Length	16.0 inches
Spring Data:	
Static Load	6,000 lbs.
Jounce Load	18,000 lbs.
Max Operating Pressure	10,000 psi adiabatic 8,900 psi isothermal
Proof Pressure:	
Spring Cavity	15,000 psi
Retraction Cavity	19,000 psi

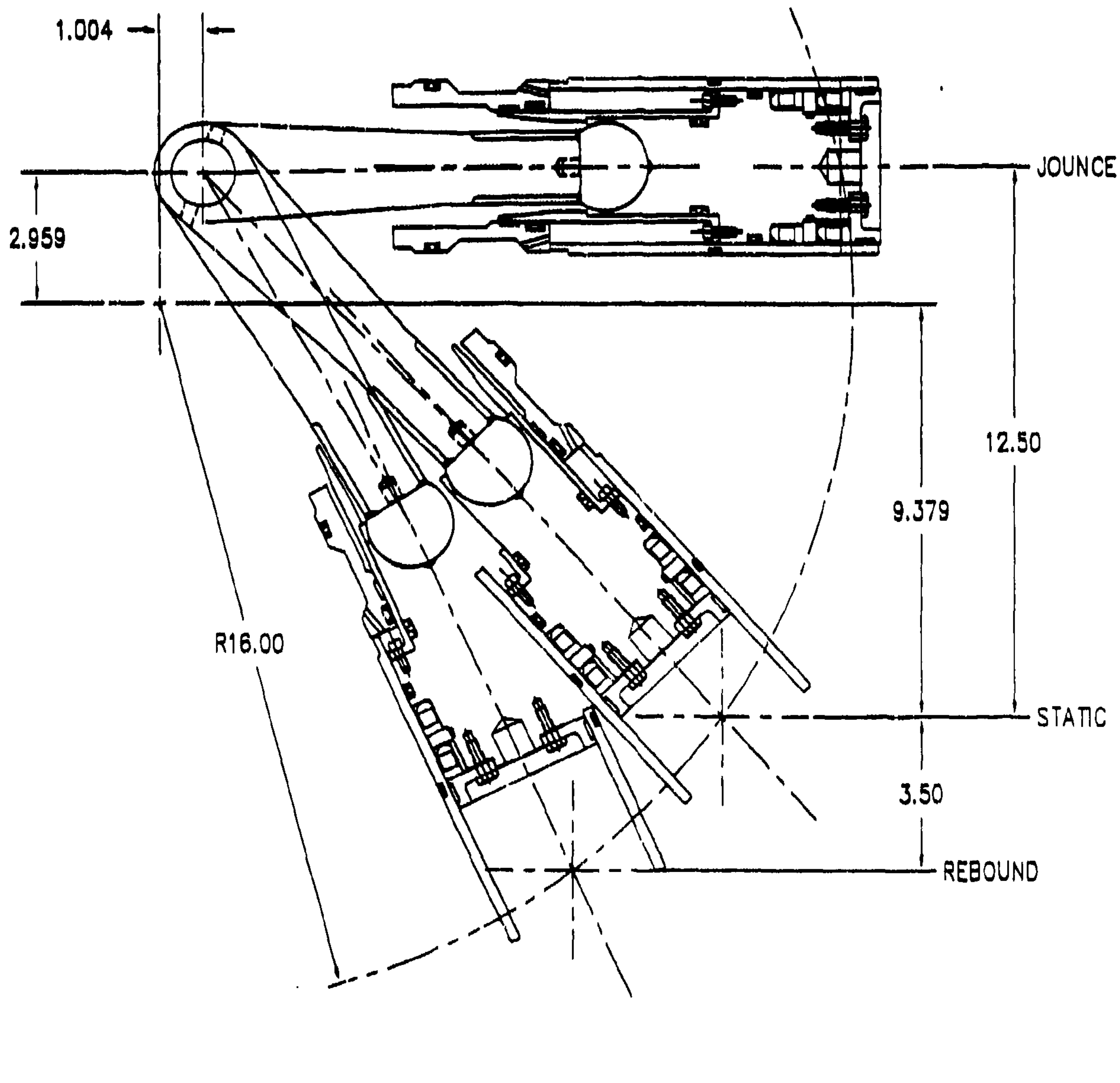


FIGURE 1 – TEST UNIT GEOMETRY

CADILLAC GAGE

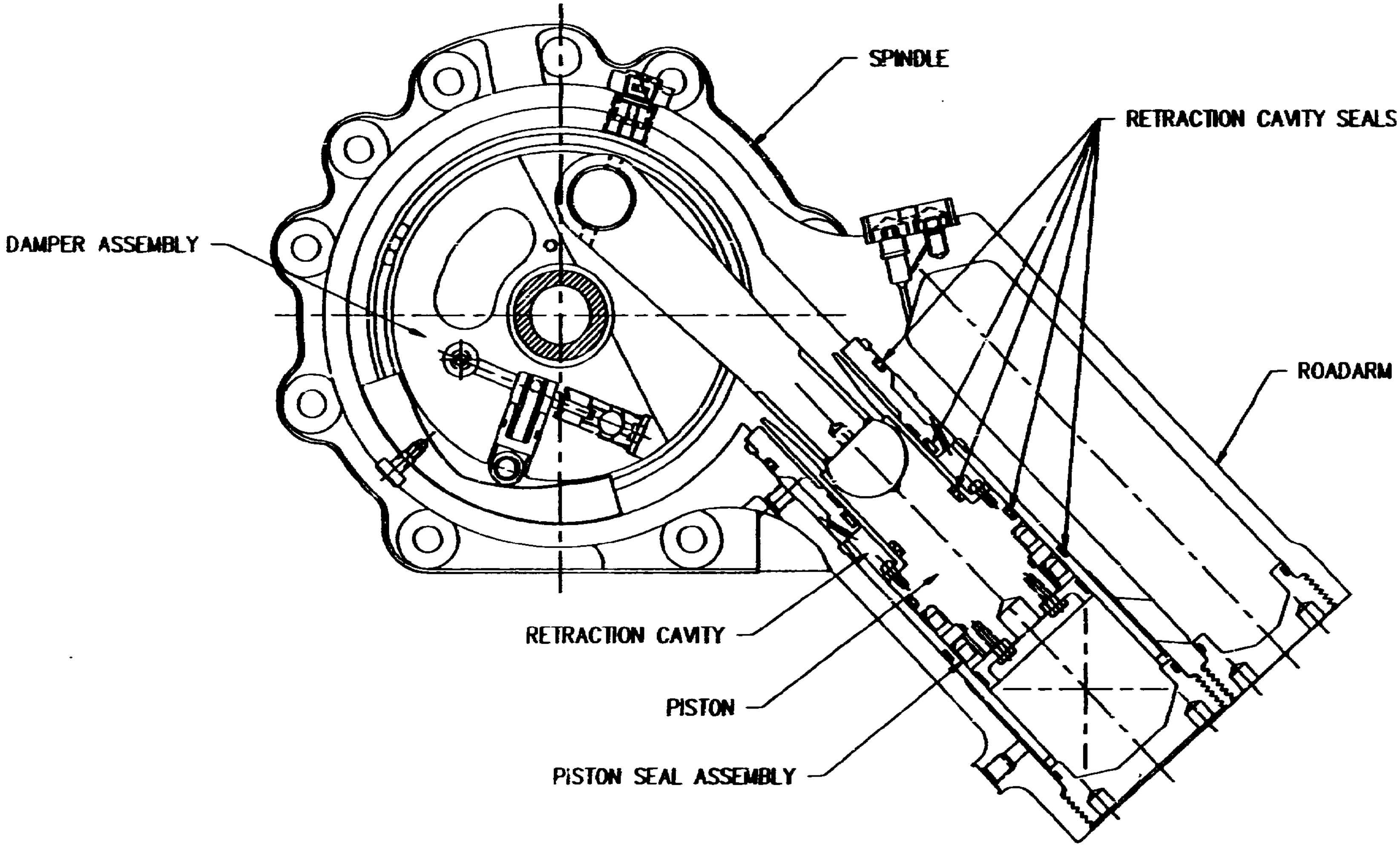


FIGURE 2 – TEST UNIT CROSS SECTION

CALCULATED PRESSURE CURVES FOR RETRACTION OPERATION (MODIFIED ISU)

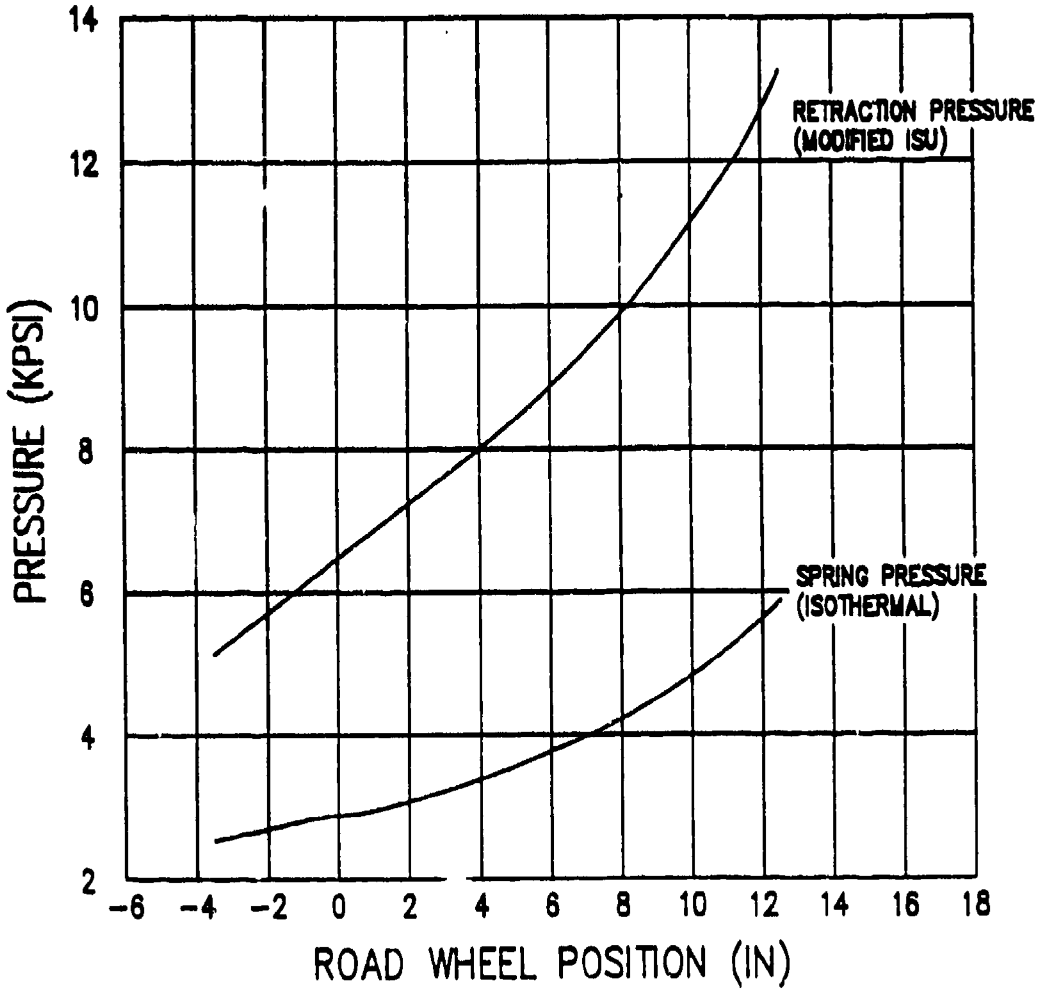


FIGURE 3

Retraction Components	1,830 psi
Control Valve	19,000 psi
Retraction:	
Retraction Time	3 minutes
Extension Time	30 seconds
Retraction Pressure	
Rebound	5,140 psi
Static	6,470 psi
Jounce (Full Retraction)	13,250 psi
Flow Rate (Per Unit):	
Retraction (Rebound to Jounce)	0.02 gpm
Extend (Jounce to Rebound)	0.12 gpm

4.2 System Concept Design

4.2.1 Retractable Hydropneumatic Suspension Unit

The concept design unit's piston and bore construction is similar in design to the unit that was developed for testing, with compensation made for proper vehicle kinematics, i.e. 17 inches of jounce travel, 18-inch roadarm length, etc. Retraction supply is internal to the unit for protection, with the connection to vehicle supply and check valve assembly located on the backside of the spindle inside the vehicle. Per DTRC's request, the unit is equipped with a limit switch, also located on the backside of the spindle. (See Figure 4, 5a, and 5b), which senses when retraction is complete and provides a signal to the operator. Water-tight integrity is maintained by an o-ring seal located on the spindle.

4.2.2 Track Tensioner

The track tensioner is a double piston type, similar to the track tensioner design used on the U.S. Army's Component Advanced Technology Test Bed (CATTB) program. The outer piston is utilized for conventional grease pack tensioning, and the inner piston for track tensioning during retraction operation. Retraction fluid supply is an integral part of the tensioner with the connection to vehicle supply located inside the vehicle. Water-tight integrity is maintained through the use of o-ring seals between the mounting bracket and vehicle hull (see Figure 6).

4.2.3 Control System

When the suspension system is to be retracted, the solenoids on the three-position, directional control valve (1) are energized, allowing vehicle hydraulic supply to the intensifier (2). With the use of position sensors (3) located on the intensifier, the three-

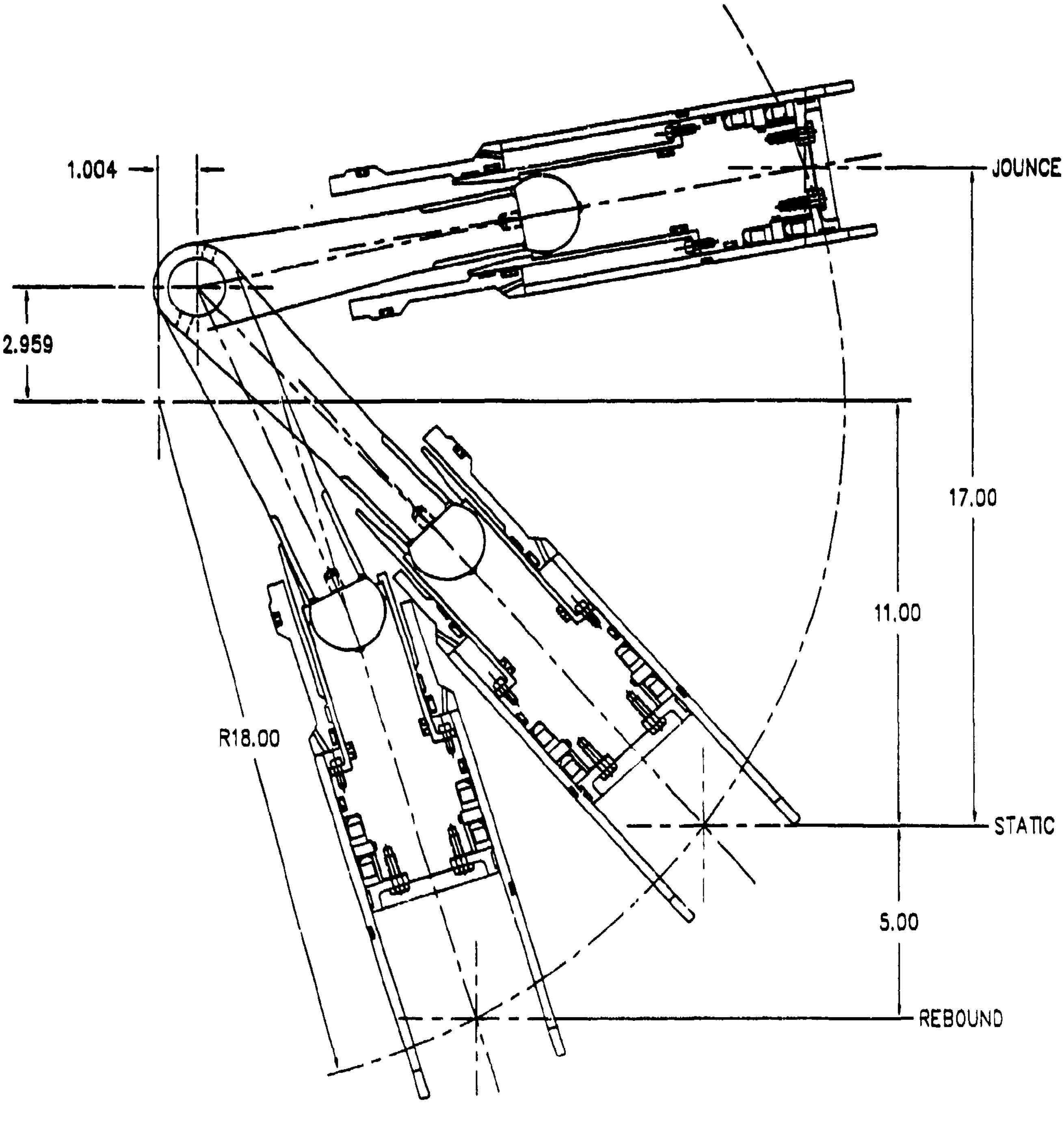


FIGURE 4 - CONCEPT DESIGN SUSPENSION UNIT GEOMETRY

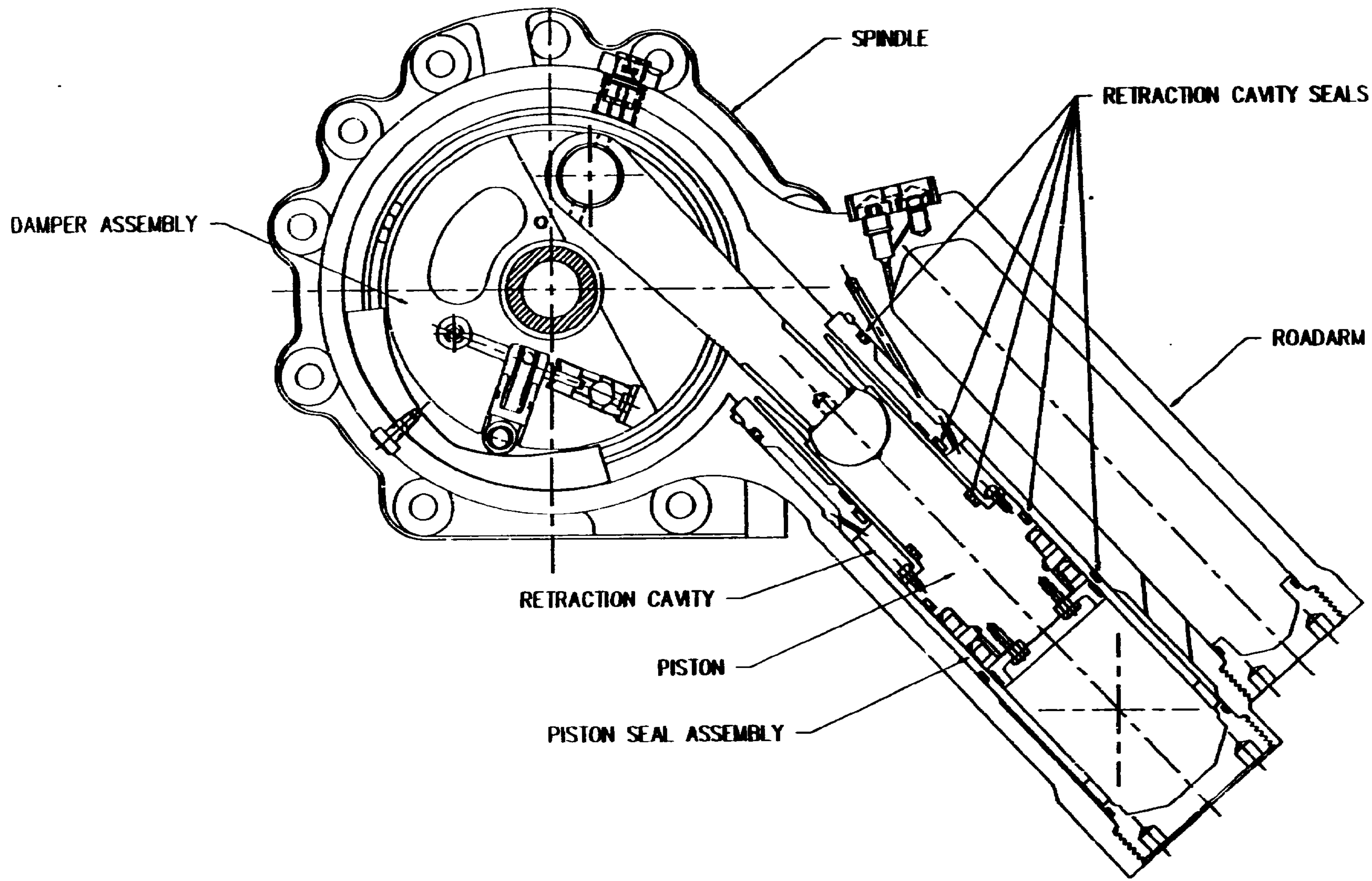


FIGURE 5.1 – CONCEPT DESIGN SUSPENSION UNIT CROSS SECTION

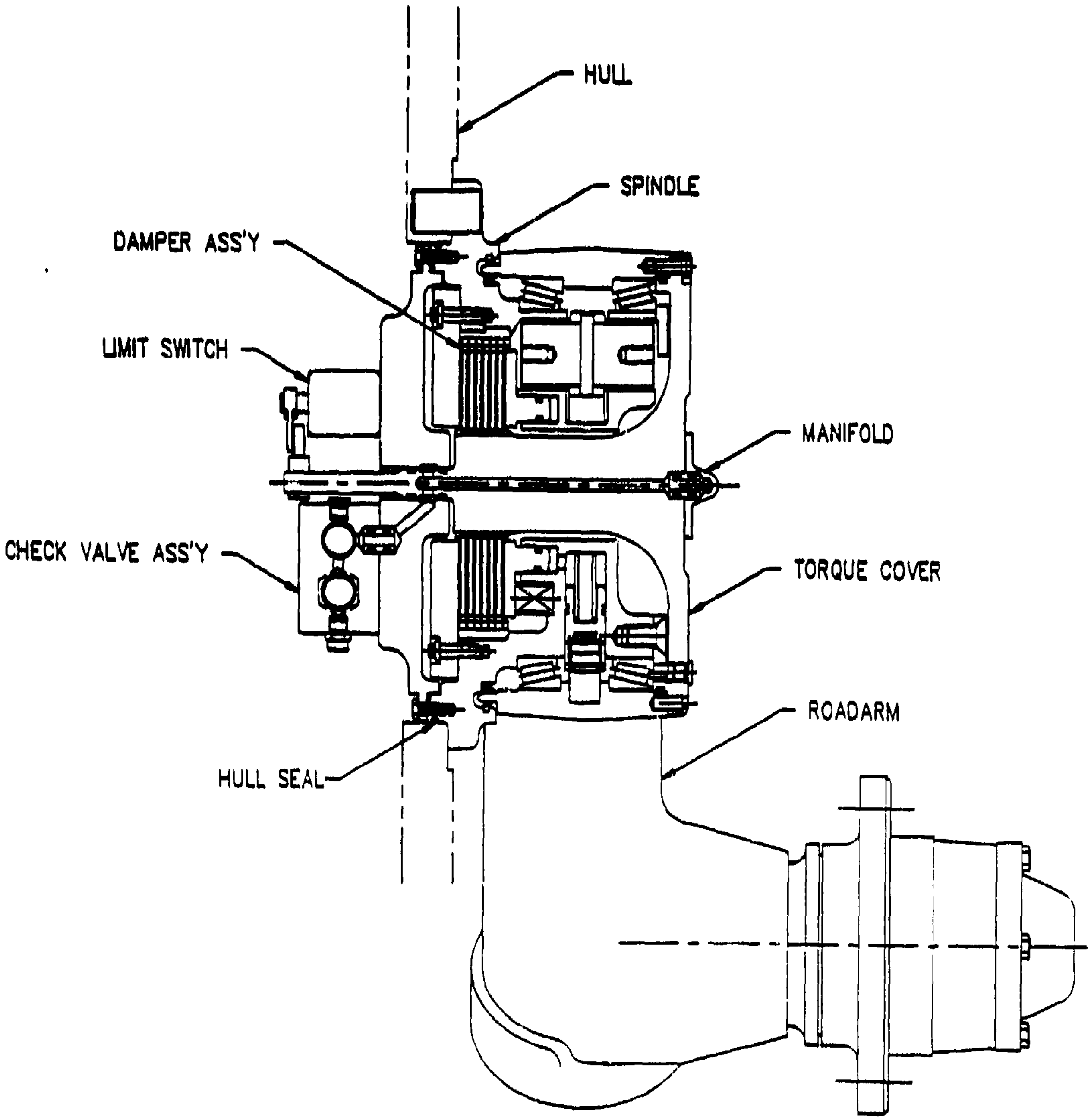


FIGURE 5b - CONCEPT DESIGN SUSPENSION UNIT CROSS SECTION

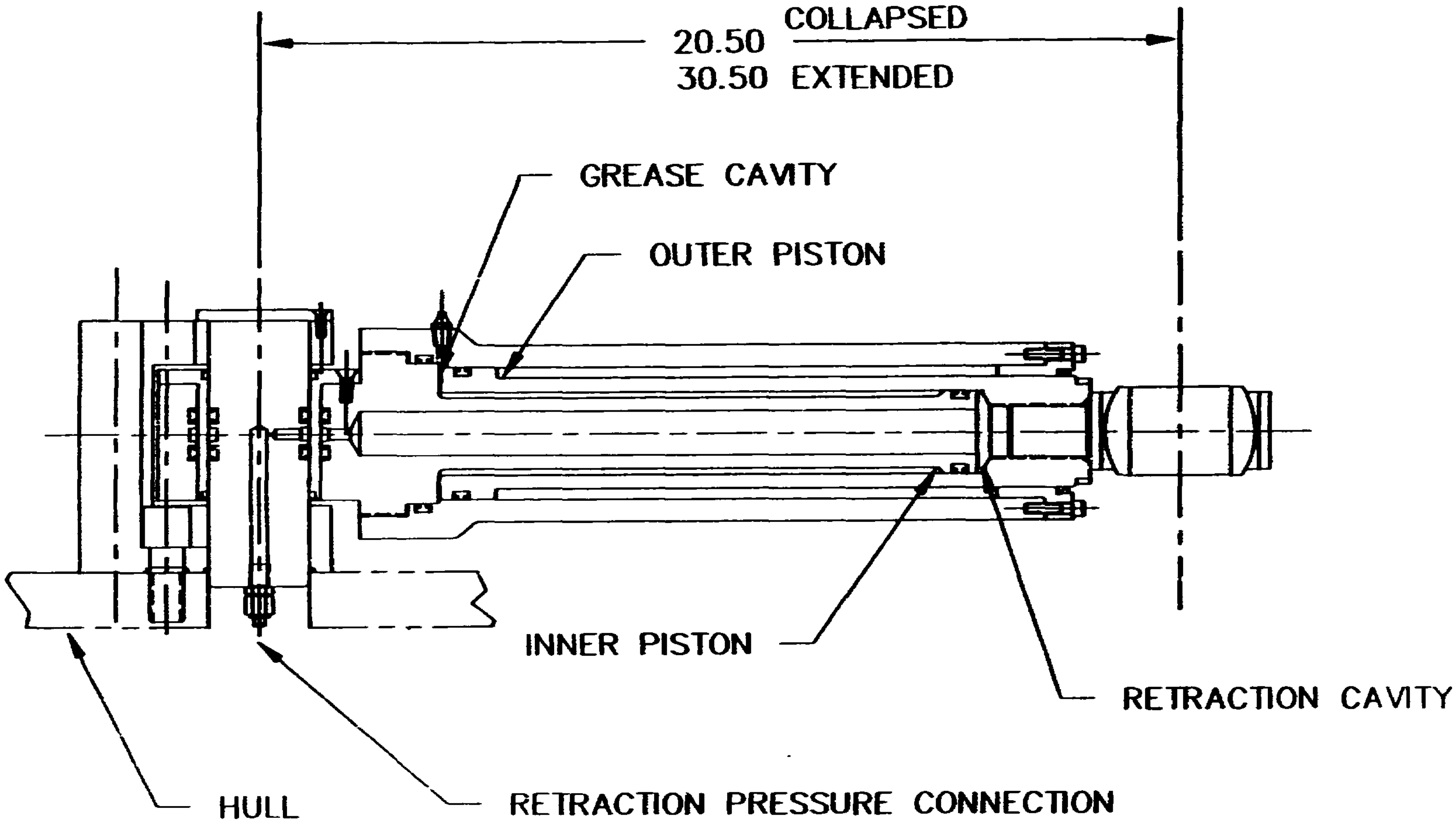


FIGURE 6 – CONCEPT DESIGN TRACK TENSIONER

position valve (1) cycles the intensifier, providing high pressure fluid to the suspension units (4) and track tensioner (5) (See Figure 7).

Retraction fluid enters each suspension unit through a spring loaded check valve (6) that has a differential cracking pressure of 20 psig. Simultaneously, the track tensioner is extended, compensating for the slack track due to retraction. When a pressure switch (7) in the retraction circuit opens at the proper retraction pressure (indicating all units are at jounce position), the directional valve (1) is de-energized, thus stopping the intensifier. An accumulator (8) in the circuit replaces any fluid lost as a result of leakage. If retraction pressure drops below a pre-determined setting, then the pressure switch (7) closes, which energizes the directional control valve (1), resuming cycling of the intensifier.

When the suspension system is to be extended, the directional valve (1) is electrically disabled and the solenoid on the two-position shut-off valve (9) is energized, dumping the retraction fluid to vehicle reservoir. (The solenoid operated shut-off valve (9) is normally closed so that in the case of power failure, the vehicle maintains retraction). Fluid in the suspension units is forced out be gas spring pressure through a second check valve (10). Each tensioner has a flow control orifice (11) to insure that the track is kept taut throughout the extend operation.

On subsequent rebound strokes of the ISU's during land operation, the remaining fluid in the units is pumped out past the second check valve (10). The spring loaded check valve (6) prevents fluid from being drawn into the units during the jounce strokes.

A manual shut-off valve (12) is provided in the circuit to allow extension of the suspension units if a power failure occurs or to allow de-activation of the shut-off valve (9) during long periods between retraction operations.

4.2.4 Weight Summary

The retractable hydropneumatic system weight includes twelve suspension units, two track tensioners, high pressure supply, control system, fluid, and necessary fittings and plumbing.

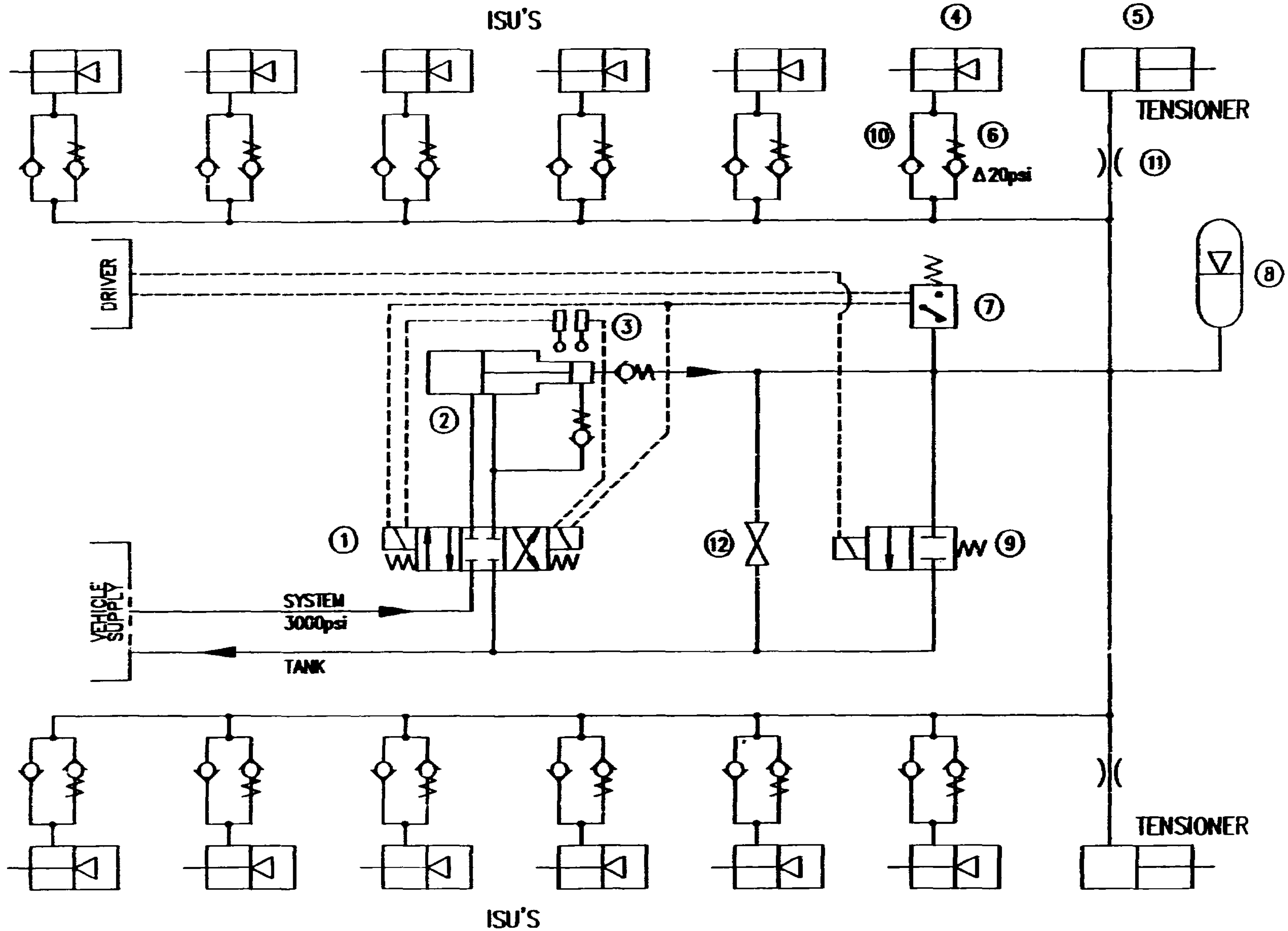
Total estimated weight is 3,982 pounds and is tabulated below:

Description	Unit	Qty	Total Weight
Suspension Unit	307 lbs	12	3,684 lbs.
Track Tensioner	91	2	182
Intensifier	---	1	20
Control System	---	1	96
	Total System Weight		3,982 lbs.

See Enclosure C for a detailed weight breakout.

5.0 Testing

5.1 Test Plan



RETRACTION CONTROL CIRCUIT
FIGURE 7

Found in Enclosure D is the test plan defining the procedure for verifying the feasibility of a retractable hydropneumatic suspension unit.

5.2 Test Schematic

As stated previously, a brass board test circuit was developed using standard components where possible. Figure 8 illustrates the schematic used for testing and Figure 9 shows the test fixture.

5.3 Test Results

5.3.1 Test Configuration

The 6K retractable test unit was mounted on the universal test stand with physical stops restricting the units movement in the rebound direction to -3.5 inches and in the jounce direction to 11.75 inches. Retraction fluid supply was provided by a commercial air/oil intensifier with regulated shop air used as input. Pressure transducers were utilized for registering the pressures in the spring and retraction cavities. Wheel spindle location was recorded using a LVDT.

With the above arrangement, the unit was raised to the retraction position and held at constant pressure for one hour. Wheel position, retraction pressure, spring pressure, and time were monitored and recorded simultaneously. At the conclusion of each hour, the intensifier air supply was disconnected and the control valve opened, allowing the unit to return to its rebound position. This cycle was repeated twenty times. At the conclusion of the twenty cycles, leakage and pressures were recorded in accordance with paragraph 5.3.5 of the test plan (see Enclosure C).

To determine fluid leak rates, fluid volumes in the spring cavity and crankcase were measured and recorded before and after testing. The variation was then divided by the hours of operation.
Control valve leakage was determined in accordance with paragraph 5.3.5 of the test plan. The results are tabulated in the test data summary sheet (see paragraph 5.3.4 of this report).

5.3.2 Retraction/Extend Timing

An intensifier with the flow and pressure characteristics necessary for integration into the universal test stand could not be procured in an acceptable time frame. Therefore, a standard commercial air/oil intensifier was utilized for testing. Although the required pressure was satisfied, the reduced flow rate resulted in a retraction time of approximately 180 seconds, rather than the 60 seconds outlined in Enclosure A.

A manual shut-off valve was incorporated into the hydraulic circuit for control of the velocity of the unit. A three-second extend operation could be achieved; however, to insure adequate data collection, tests were conducted with an extend time of approximately 30 seconds.

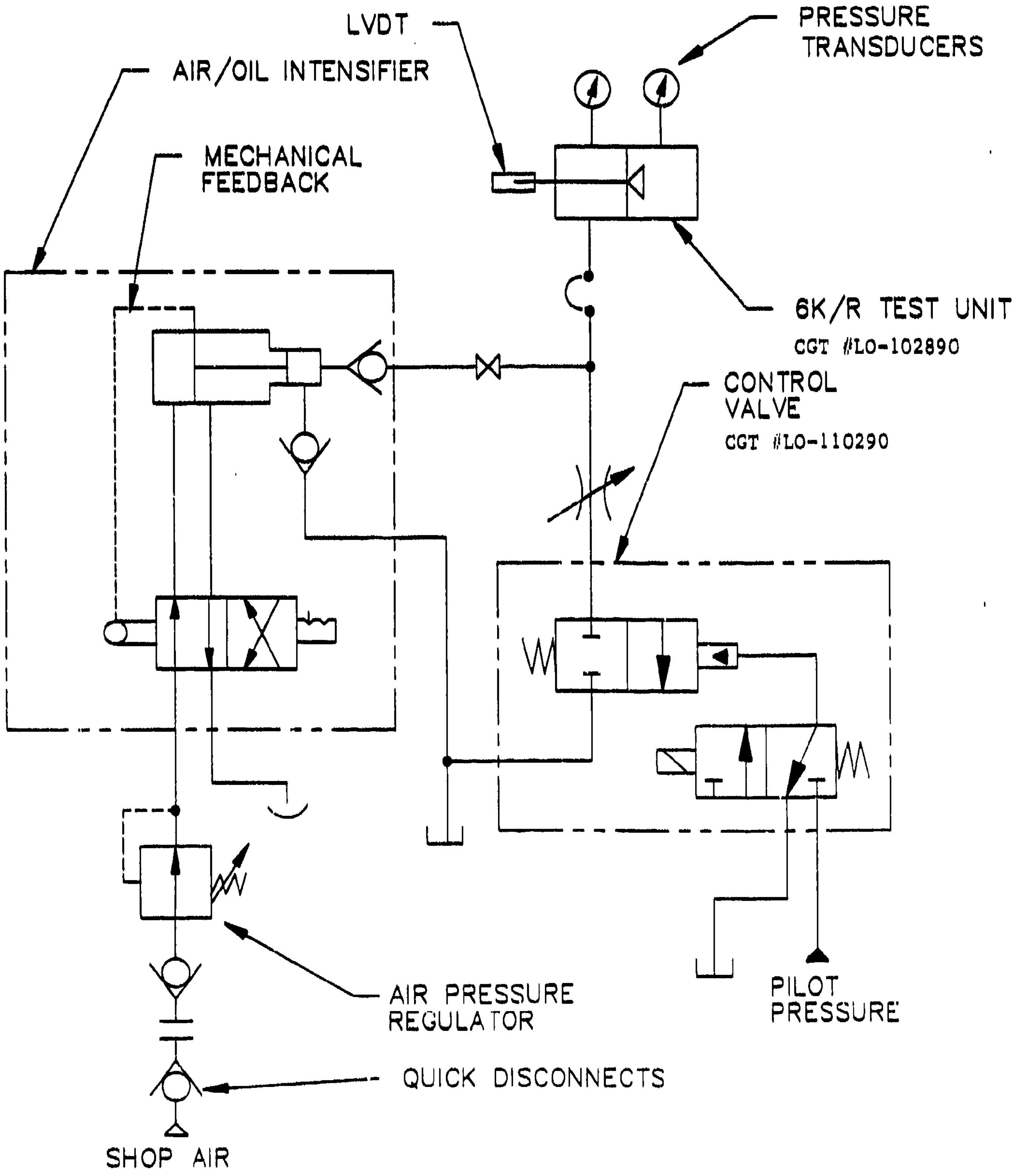


FIGURE 8 – TEST SCHEMATIC

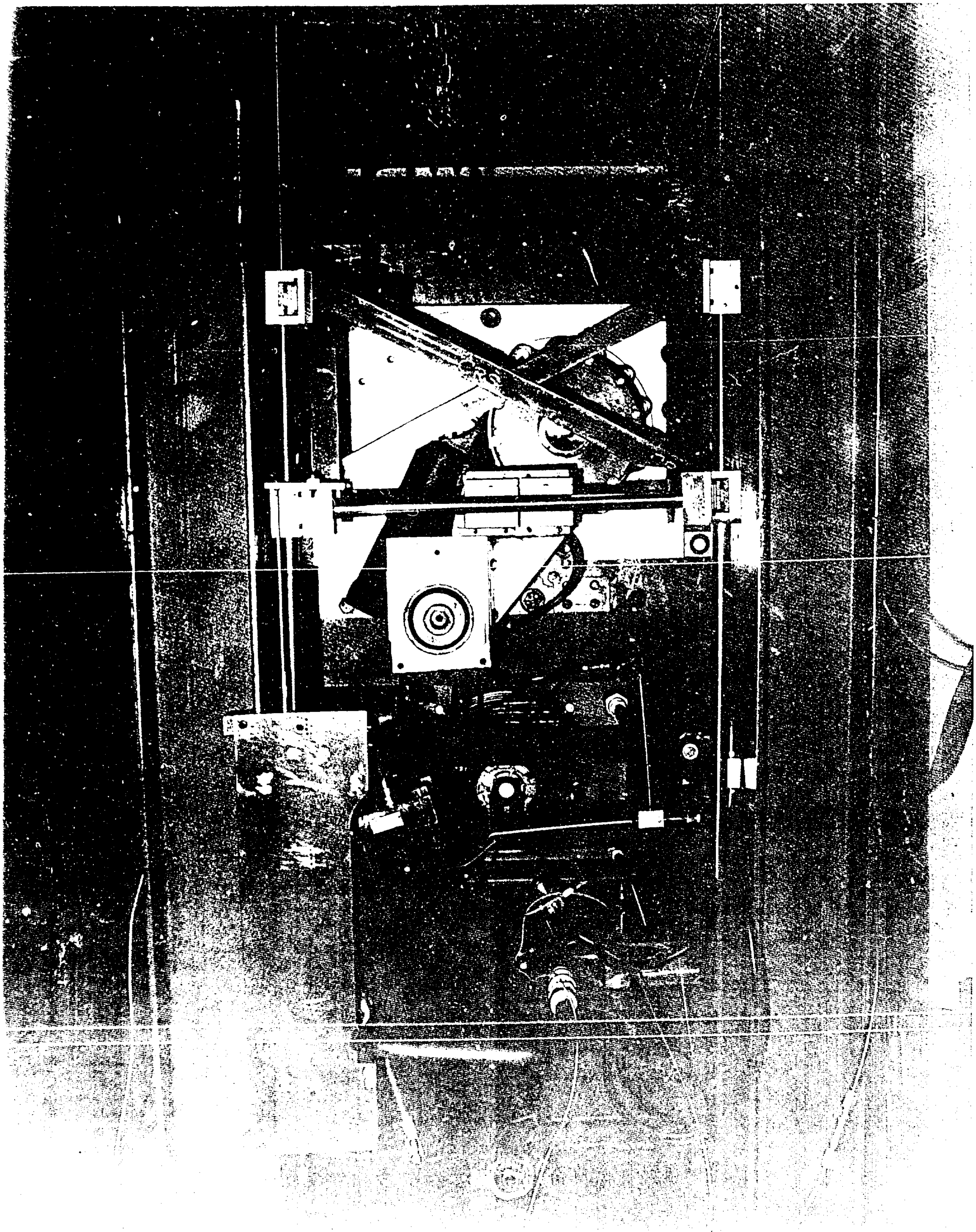


FIGURE 9 - TEST CELL

5.3.3 Leak Test Cycle

As a result of the air/oil intensifier not being a constant displacement device, the flow delivered decreased as the retraction pressure raised. With the higher flow rate at the beginning of the cycle, the spring gas tends to react toward the adiabatic process, with reduction of this trend as the unit reaches jounce more slowly. This is illustrated by the spring and retraction pressure curves in Figure 10.

The calculated retraction curve was derived by assuming an isothermal spring process and increasing the resultant retraction pressure by 10% to overcome roadarm weight, damper friction, and seal friction. This estimate is based on previous 6K test data and equates to a 2.2:1 ratio to spring pressure. As illustrated in Figure 11, the measured retraction pressure is greater than was anticipated, starting with an approximate ratio of 2.8:1 and concluding with a 2.3:1 ratio.

The greater retraction pressure is, in part, a result of the additional seal friction in the retraction cavity and the weight of the added retraction components, which are shown in Figure 12.

The reduction in pressure ratios are owed to the increasing mechanical advantage through unit kinematics, which begins to overcome the friction as the roadarm achieves jounce.

When the unit is at jounce and the intensifier blocked from the circuit, the spring gas continues to cool until it reaches thermal equilibrium with the ambient. The curves shown in Figures 13 and 14 reflect this process. As can be seen in Figure 15, the retraction pressure decreases accordingly, maintaining a 2.3:1 ratio throughout the sample time. The position of the roadarm versus time was also recorded to evaluate drift of the suspension unit due to internal leakage. No appreciable drift was noted, as is illustrated in Figure 16. The extend pressures were also recorded for the retraction chamber and spring system. These pressures versus position are shown in Figure 17.

5.3.4 Test Data Summary

Test Unit Number	LO-102890
Ambie t Temperature	294°K ± 10°
Total No. of Hours of Operation	23 Hours
Proof Pressures:	
Spring Cavity	15,000 psi
Retraction Cavity	15,000 psi @ 11.75 inch position 19,000 psi @ 6.5 inch position
Retraction Components	1,830 psi(8,514-lb load, tension)
Control Valve	19,000 psi
Measured Data:	
Rebound Position	-3.75 inches

Jounce Position		11.75 inches
Retraction Pressure (@ Jounce)		13,254 psi
Spring Pressure:		
	Pre-test	Post-test
Rebound	2,363 psi	2,324 psi
Static	2,804 psi	2,756 psi
Jounce (11.75 inches and 3,000 seconds)	5,645 psi	5,469 psi
Volumes:		
Spring	930 cc	1,019 cc
Crankcase	1,650 cc	1,650 cc

Leak Rates:	
Spring Cavity	0 cc/hr.
Retraction Cavity	4.45 cc/hr.
Control Valve	(1) drop/hr.
Retraction Pressure (Spring Vented)	510 psi
Retraction Pressure (Spring Vented, Damper Disabled)	220 psi
Breakaway Pressures:	
Retraction (From Rebound)	
Retraction Cavity	6,431 psi
Spring Cavity	2,422 psi
Difference	4,009 psi
Extend (From Jounce)	
Retraction Cavity	5,716 psi
Spring Cavity	5,229 psi
Difference	487 psi

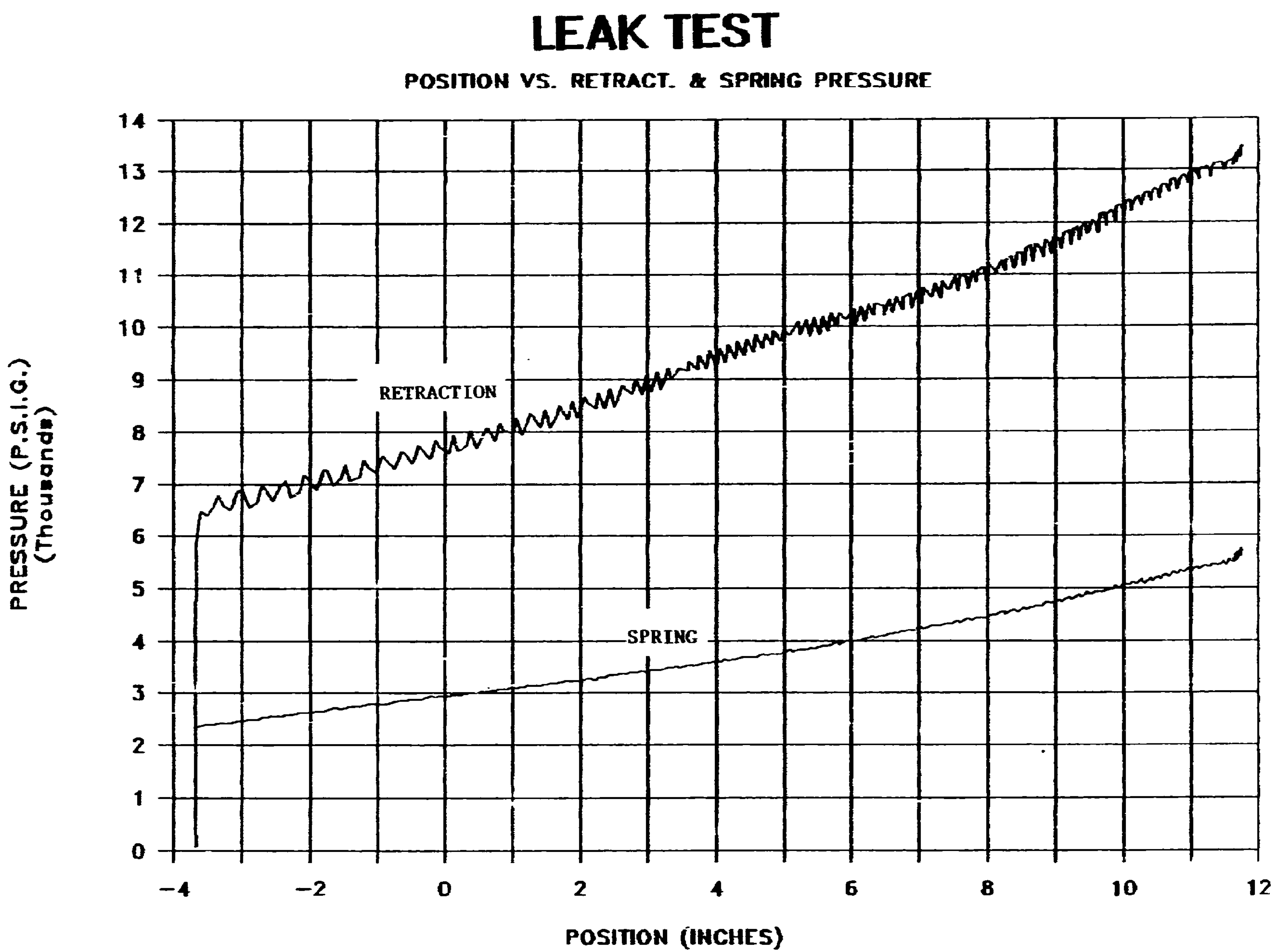

LEAK TEST
POSITION VS. RETRACT. & SPRING PRESSURE
PRESSURE (P.S.I.G.)
(Thousands)
14
13
12
11
10
9
8
7
6
5
4
3
2
1
0
RETRACTION
SPRING
−4
−2
0
2
4
6
8
10
12
POSITION (INCHES)

FIGURE 10

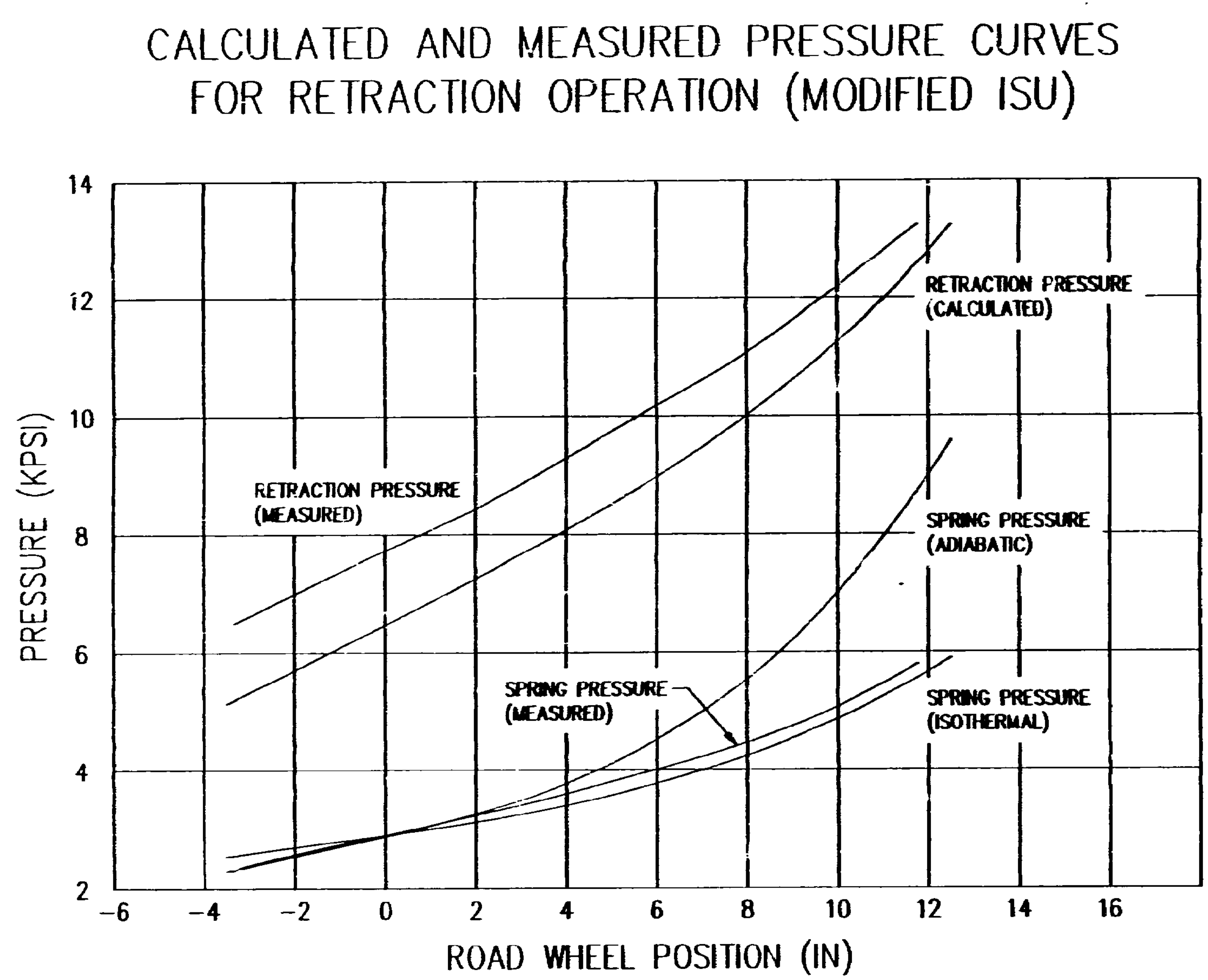

CALCULATED AND MEASURED PRESSURE CURVES
FOR RETRACTION OPERATION (MODIFIED ISU)
PRESSURE (KPSI)
14
12
10
8
6
4
2
-6
-4
-2
0
2
4
6
8
10
12
14
16
ROAD WHEEL POSITION (IN)
RETRACTION PRESSURE (CALCULATED)
RETRACTION PRESSURE (MEASURED)
SPRING PRESSURE (ADIABATIC)
SPRING PRESSURE (MEASURED)
SPRING PRESSURE (ISOTHERMAL)

FIGURE 11

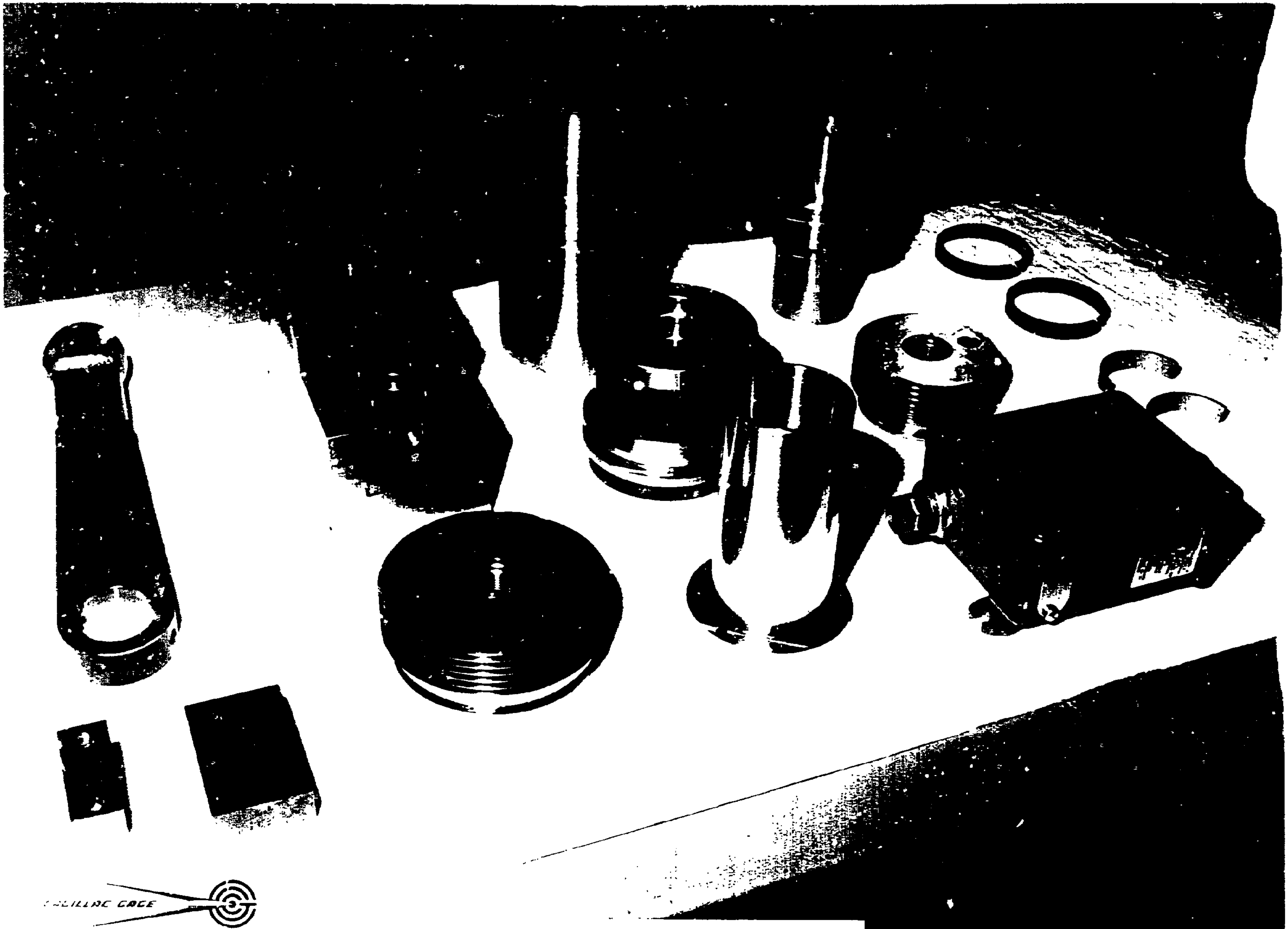


FIGURE [illegible] - RETRACTION COMPONENTS

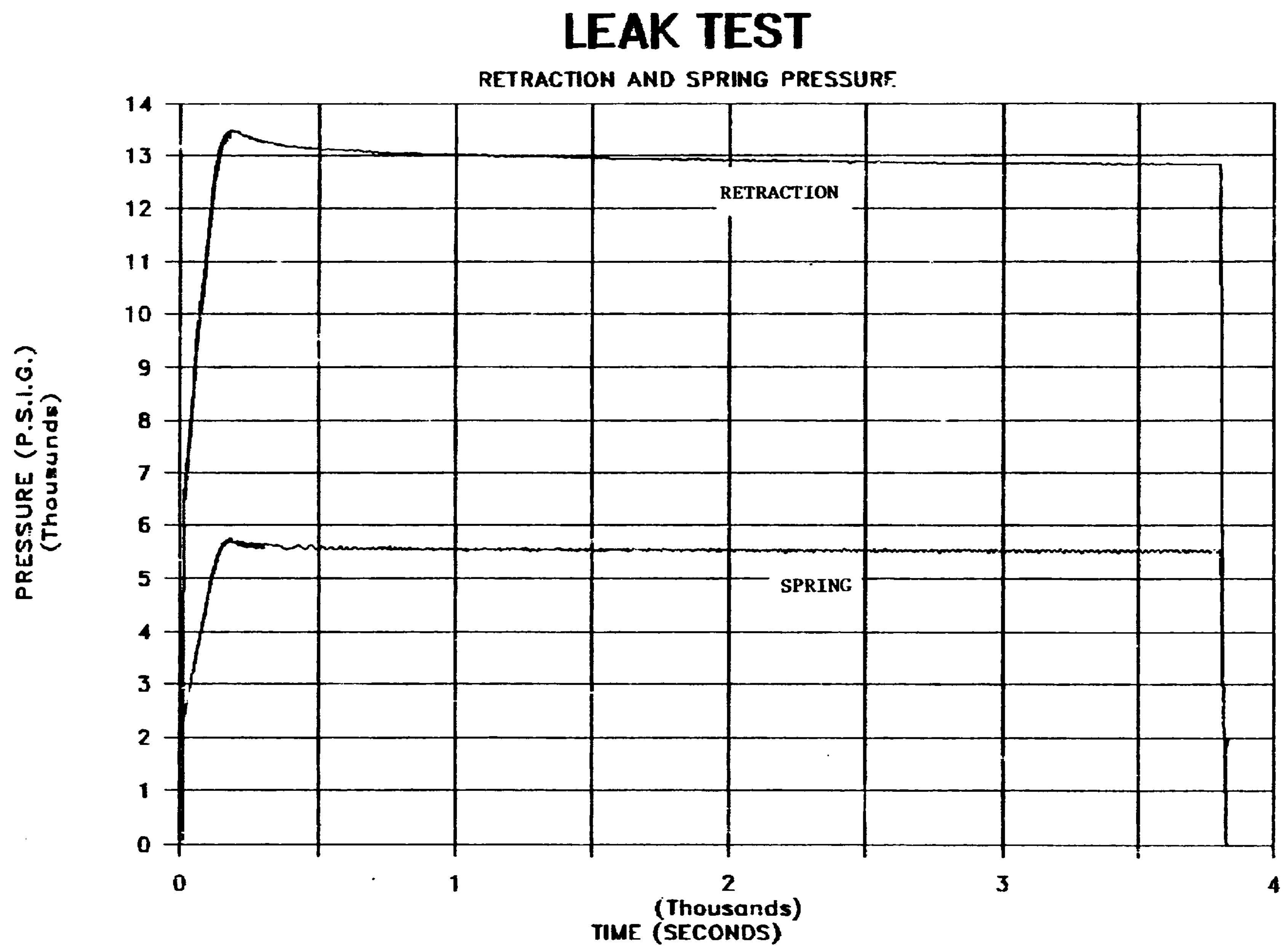
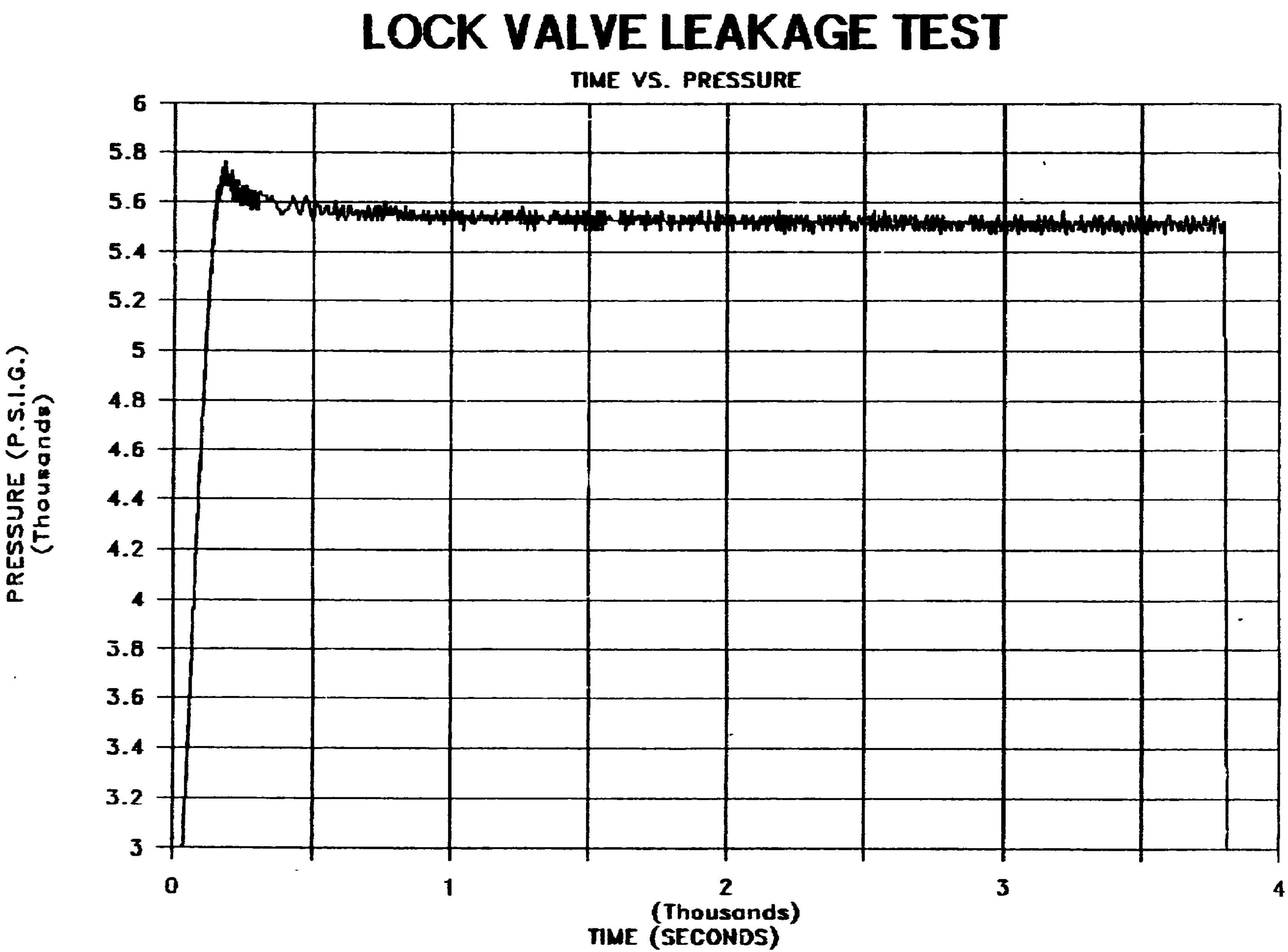

LEAK TEST
RETRACTION AND SPRING PRESSURE
RETRACTION
SPRING
PRESSURE (P.S.I.G.)
(Thousands)
14
13
12
11
10
9
8
7
6
5
4
3
2
1
0
0
1
2
3
4
(Thousands)
TIME (SECONDS)

FIGURE 13



LOCK VALVE LEAKAGE TEST
TIME VS. PRESSURE
PRESSURE (P.S.I.G.)
(Thousands)
6
5.8
5.6
5.4
5.2
5
4.8
4.6
4.4
4.2
4
3.8
3.6
3.4
3.2
3
0
1
2
3
4
(Thousands)
TIME (SECONDS)

FIGURE 14

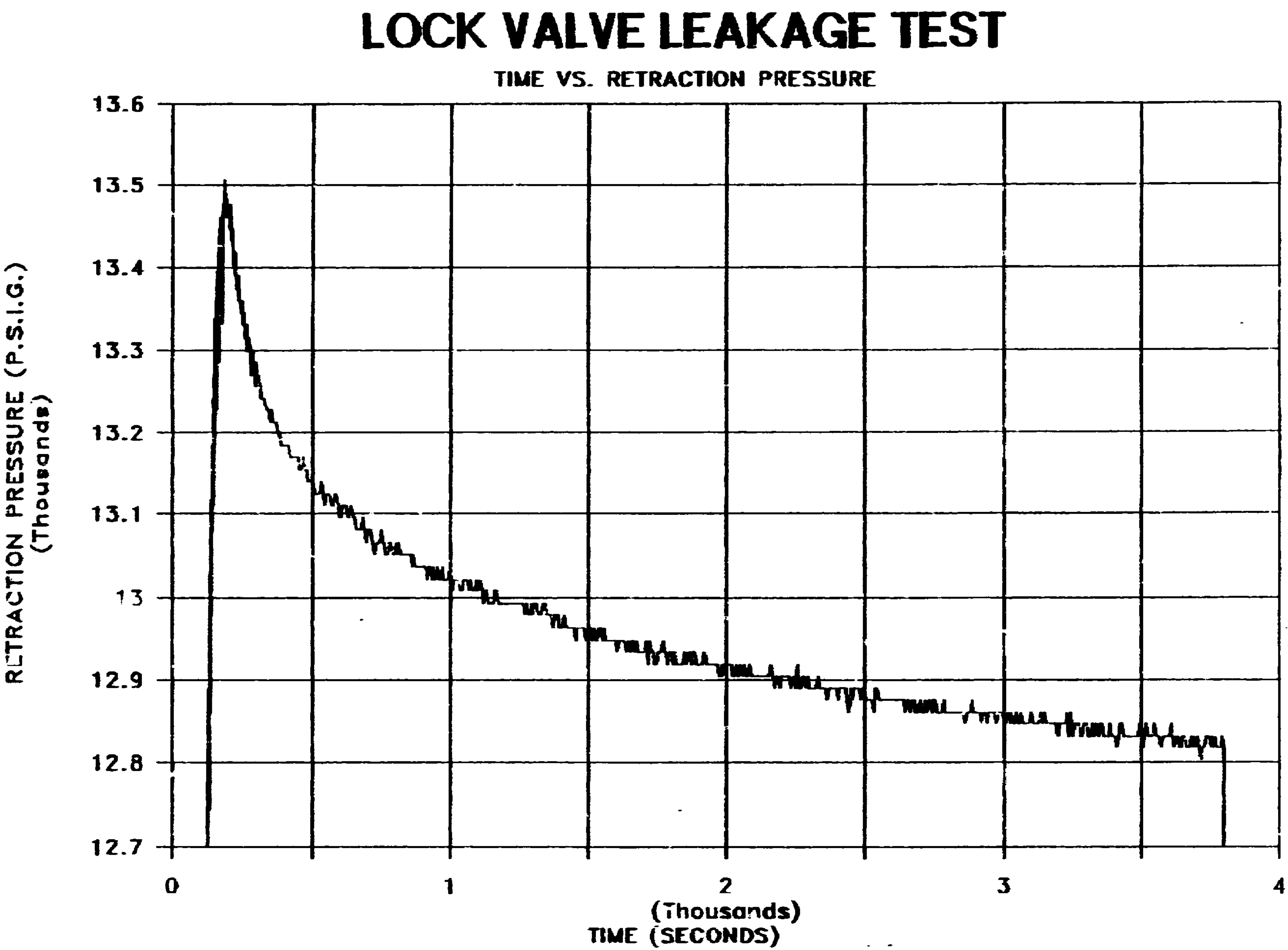
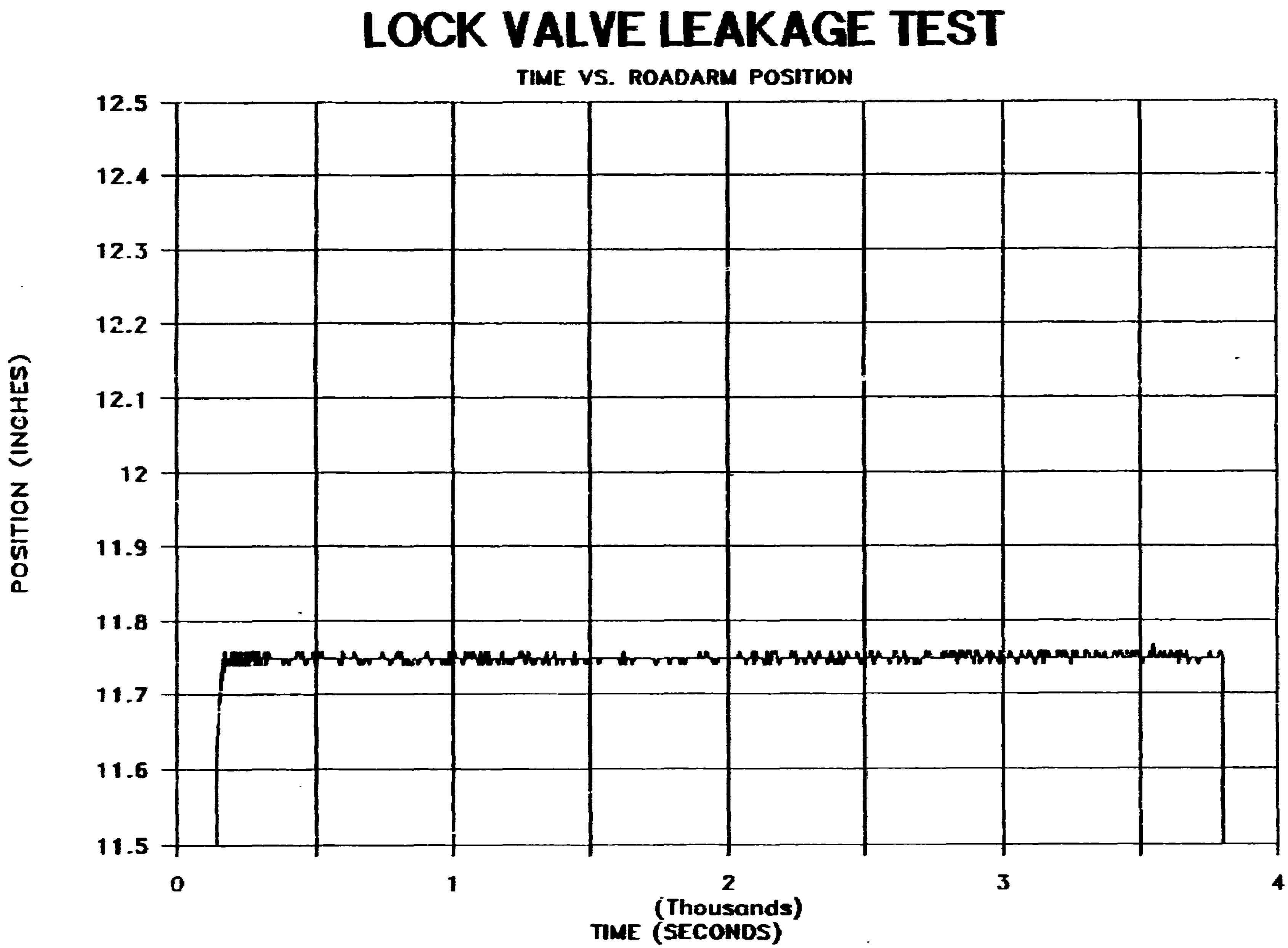
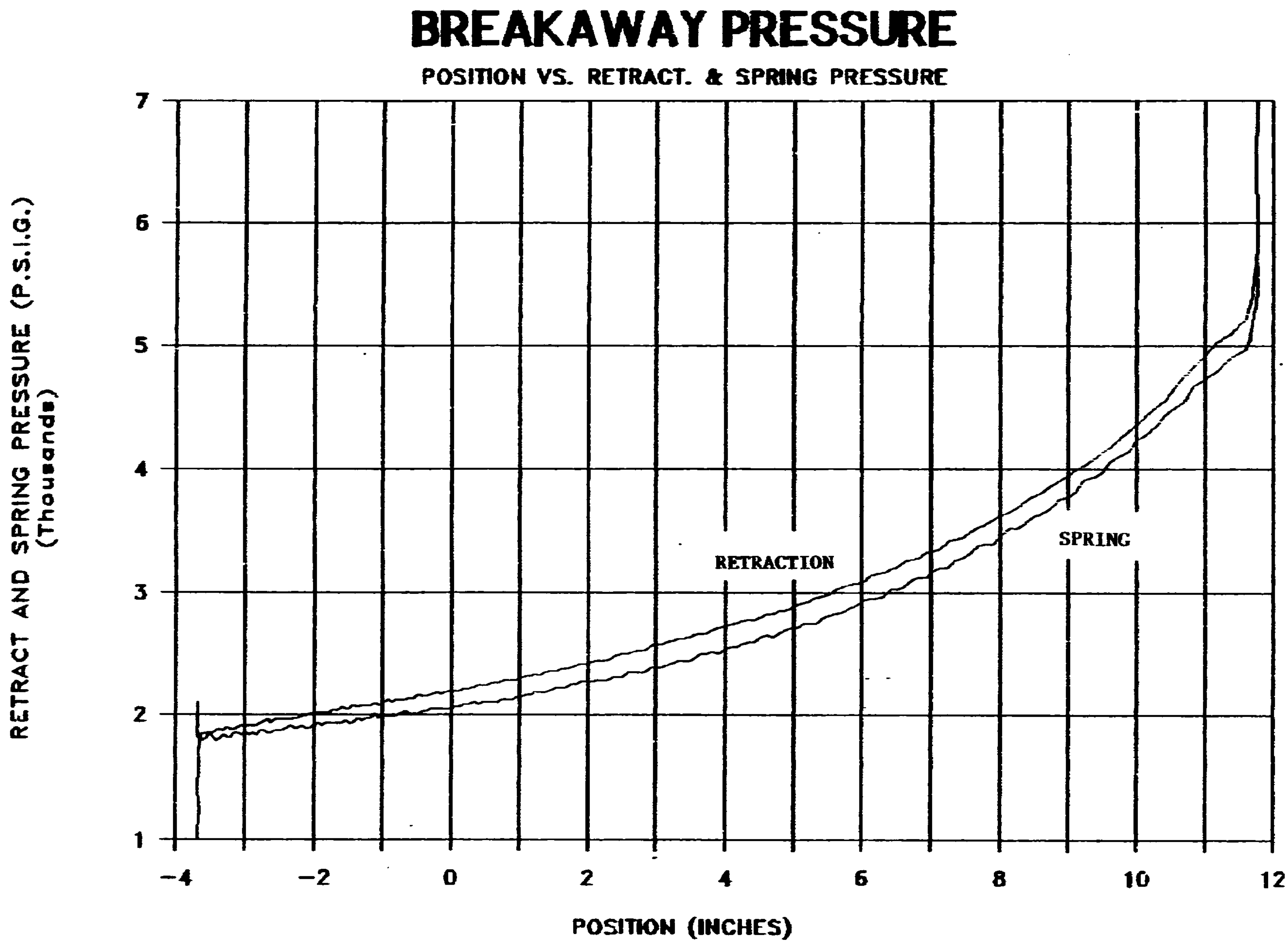

LOCK VALVE LEAKAGE TEST
TIME VS. RETRACTION PRESSURE
RETRACTION PRESSURE (P.S.I.G.)
(Thousands)
13.6
13.5
13.4
13.3
13.2
13.1
13
12.9
12.8
12.7
0
1
2
3
4
(Thousands)
TIME (SECONDS)

FIGURE 15



LOCK VALVE LEAKAGE TEST
TIME VS. ROADARM POSITION
POSITION (INCHES)
12.5
12.4
12.3
12.2
12.1
12
11.9
11.8
11.7
11.6
11.5
0
1
2
3
4
(Thousands)
TIME (SECONDS)

FIGURE 16



BREAKAWAY PRESSURE
POSITION VS. RETRACT. & SPRING PRESSURE
RETRACT AND SPRING PRESSURE (P.S.I.G.)
(Thousands)
7
6
5
4
3
2
1
RETRACTION
SPRING
-4
-2
0
2
4
6
8
10
12
POSITION (INCHES)

FIGURE 17

ENCLOSURE A

PROPOSAL TO
DAVID TAYLOR RESEARCH CENTER
WITH STATEMENT OF WORK

8-111-633

PROPOSAL

TO

DAVID TAYLOR RESEARCH CENTER

FOR

LIGHT WEIGHT RETRACTABLE SUSPENSION SYSTEM

TECHNICAL PROPOSAL

LIGHT WEIGHT RETRACTABLE SUSPENSION SYSTEM

Cadillac Gage Textron (CGT) is pleased to submit a proposal for the design of a light weight fully retractable suspension system for a 65,000 pound tracked amphibian vehicle and for the fabrication and testing of the systems critical components.

1.0 DESCRIPTION

The suspension/retraction system consists of 6K ISU's modified to incorporate an In-Arm Retraction Mechanism (6K ISU/R), a high pressure hydraulic power supply, a control manifold and valve assembly, track tensioners, interconnecting plumbing, and mounting brackets.

The resultant suspension/retraction system features:

- A retraction system which does not compromise the reliability of the self-contained ISU.
- A low power retraction system which utilizes the vehicle hydraulic power supply as the primary energy source.
- A lightweight/low cost suspension/retraction system which has a minimum impact on the vehicles interior volume.
- A capability for fast extension both on land and in the water.
- A high degree of commonality with the AAV-7 Suspension System.
- A retraction system which does not require vehicle hydraulic power to sustain the retracted suspension after the initial retraction of the system.

Figure 1 shows the road arm geometry of the 6K ISU/R when mounted on the vehicle hull with the center of rotation of the roadarm located 10 inches above the bottom of the hull. The 10 inch dimension is required to provide adequate clearance between the track and the ISU in the retracted position. An increase in the length of the roadarm from 16 inch to 18 inch will be required to permit the desired 5 inch rebound travel within the allowable rotation of the roadarm. In addition, as shown on sheet 1 of concept drawing LO-030189-1, the length of the arm is further increased to provide space for the retraction mechanism which is incorporated between the piston and the connecting rod of the in-arm slider/crank.

This increase in the length, as shown on sheet 2 of concept drawing LO-030189-1, mandates that the minimum spacing between adjacent 6K ISU/R be 30.75 inch.

During the design activity, efforts will be made to reduce the 4.88 inch and thus the 30.75 inch dimensions to both permit improved load distribution between the road wheel when mounted on a vehicle whose center of gravity does not coincide with the mid-position of the track envelope and to reduce the weight of the 6K ISU/R. The accumulator length and/or diameter will then be optimized to provide the required spring characteristic and structural properties at a minimum weight.

A schematic diagram of the retraction system is shown in Figure 2. When the suspension system is to be retracted the solenoid valve is energized and the vehicle engine driven 3000 PSI hydraulic power provides pressure fluid at an average flow rate of 10.8 GPM to the inlet port of the intensifier. The intensifier has an amplification of 3.5 to 1.0 and provides at its output port 10,500 PSI pressure fluid at an average flow rate of 2.4 GPM to retract the twelve 6K ISU/R and extend the two track tension mechanisms in 60 seconds. Upon reaching the required 10,500 PSI output pressure, the intensifier ceases to recycle, the engine may be turned off and the check valve in the high pressure line and the two way solenoid valve in the return line prevent the extension of the suspension system. When the suspension system is to be redeployed the solenoid valve is de-energized permitting the stored energy in the hydropneumatic springs of the ISU's and in the track to pump the 2.4 gallons of fluid in the retraction system through the check valve in the return line back to the reservoir in approximately three seconds. The check valve in the return line on subsequent jounce strokes of the ISU's prevents fluid from being drawn back from the reservoir into the retraction system.

A preliminary weight estimate for the suspension/retraction is shown on Figure 3. This estimate of the wet weight of the system includes all of the system components, plumbing, harnessing, and mounting hardware from the hull up to but not including the road wheel required for the installation and operation of the suspension/retraction system. It does not include the weight of the vehicle hydraulic power supply or of the compensating idler arm.

2.0 STATEMENT OF WORK

CGT shall perform a system design for a fully retractable hydropneumatic suspension system for a tracked amphibian vehicle. The system shall include the current 6K ISU modified to incorporate an In-Arm Retraction Mechanism, an extendable track tension and compensating idler arm mechanism, a high pressure power supply, a retraction/extension control system, and the required plumbing, harnessing, and mounting brackets. A report and level 1 drawings shall be generated for this effort. The report will include an overall description of the system.

CGT shall modify a 6K ISU to incorporate the features and fabricate a brassboard high pressure supply and retraction/extension control system in order to laboratory test the performance, durability, and reliability of the critical system components. A test report will be generated summarizing this effort and providing the test results.

CGT shall host three reviews at its facility during the course of this effort. Review dates shall be at the approximate 50% and 100% completion of the design effort and during the performance testing of the system critical components. Monthly progress reports will include status of ISU/R.

2.1 Installation

CGT shall detail the means by which the host vehicle would have to be modified to accept the suspension/retraction system including required mechanical and hydraulic interfaces. Any intrusion into the vehicles interior will be defined and means by which the water tight integrity of the vehicle will be maintained will be described.

2.2 Vehicle Hydraulic System

CGT shall design the retraction system to be compatible with 30 wt. hydraulic fluid. Vehicle hydraulic requirements will be defined and hydraulic hardware unique to the retraction system will be detailed and a weight estimate provided.

2.3 Design Characteristics

CGT shall develop the design of the suspension/retraction system to meet all of the characteristics specified in the SOW.

2.4 Weight

CGT will provide a detailed weight calculation for all of the system components including the weight of that current hardware which is useable and of new components. Efforts will be made during the design activity to minimize the system weight.

2.5 Schedule

A list of the tasks to be accomplished during this development effort and a schedule for their accomplishment is shown in Figure 4.

6K ISU/R ROADARM GEOMETRY

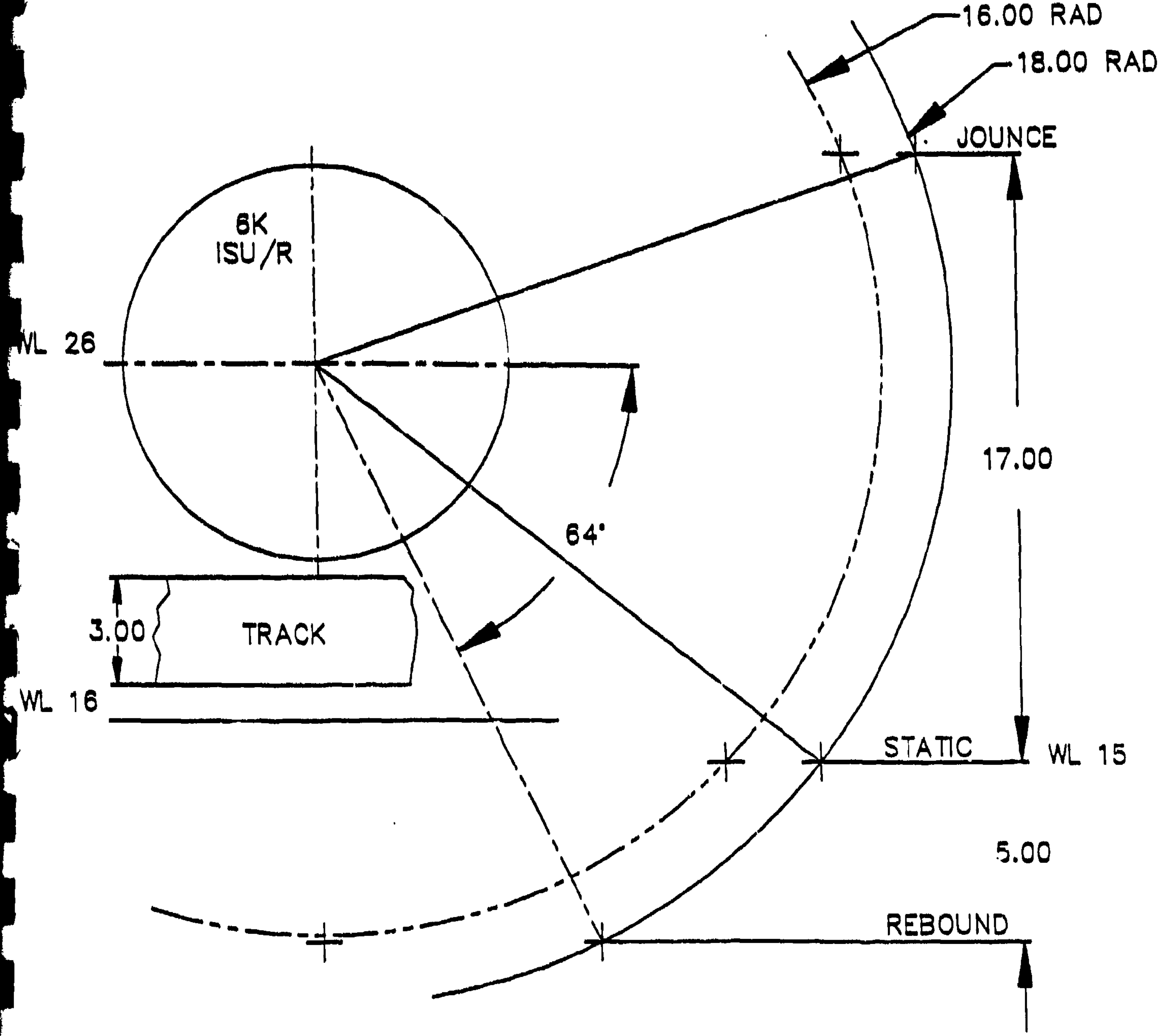


FIGURE 1.

6K ISU/R
RETRACTION SYSTEM

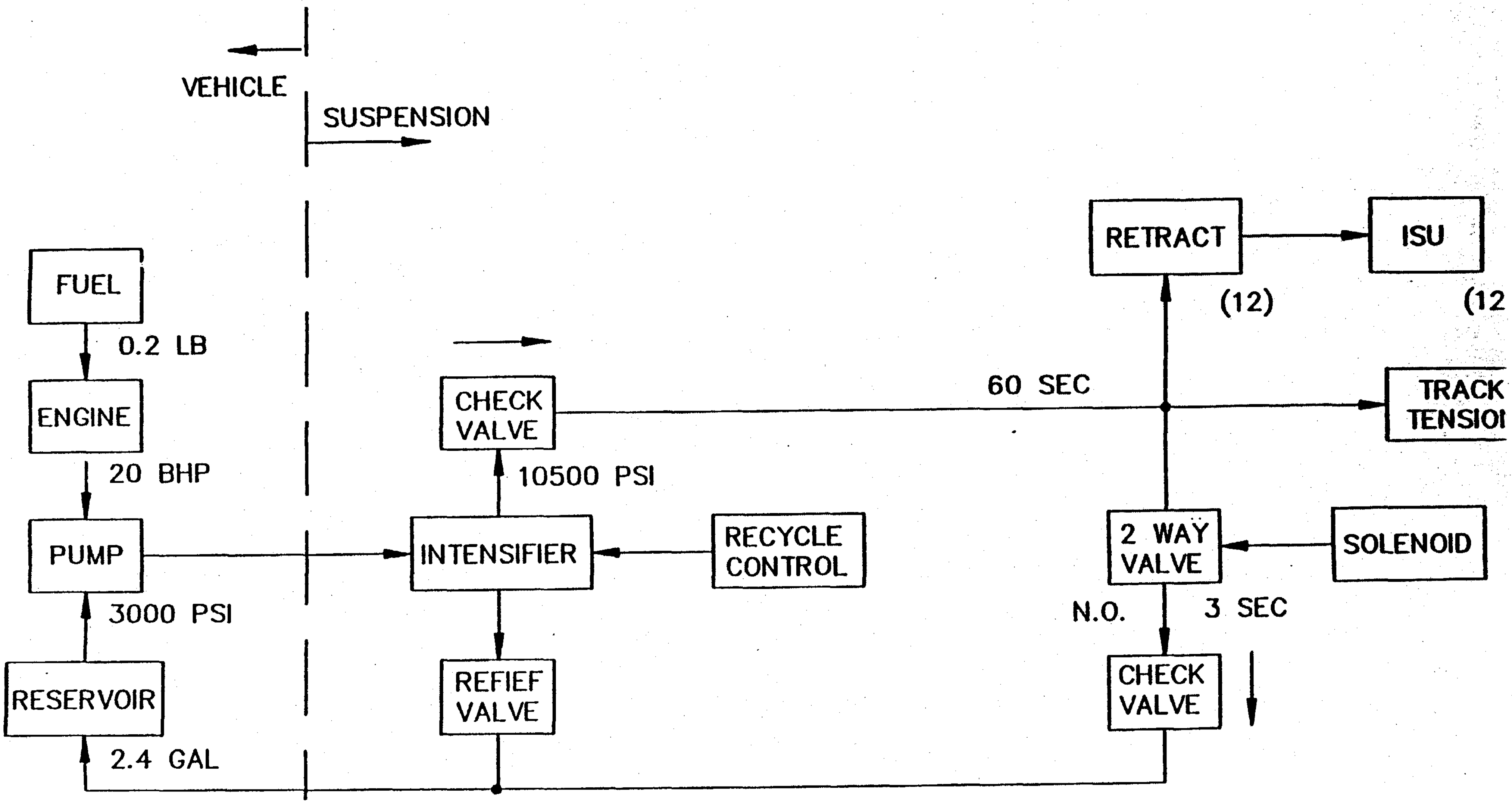


FIGURE 2.

6K ISU/R

WEIGHT ESTIMATE

ISU (MODIFIED 6K)	309 LB. (12)
TRACK TENSION ACTUATOR	31 LB. (2)
HIGH PRESSURE SUPPLY	88 LB.
CONTROL SYSTEM	36 LB.
SUSPENSION SYSTEM	3894 LB.

NOTE: BALLISTIC PROTECTION
.50 STEEL (MINIMUM)

FIGURE 3.

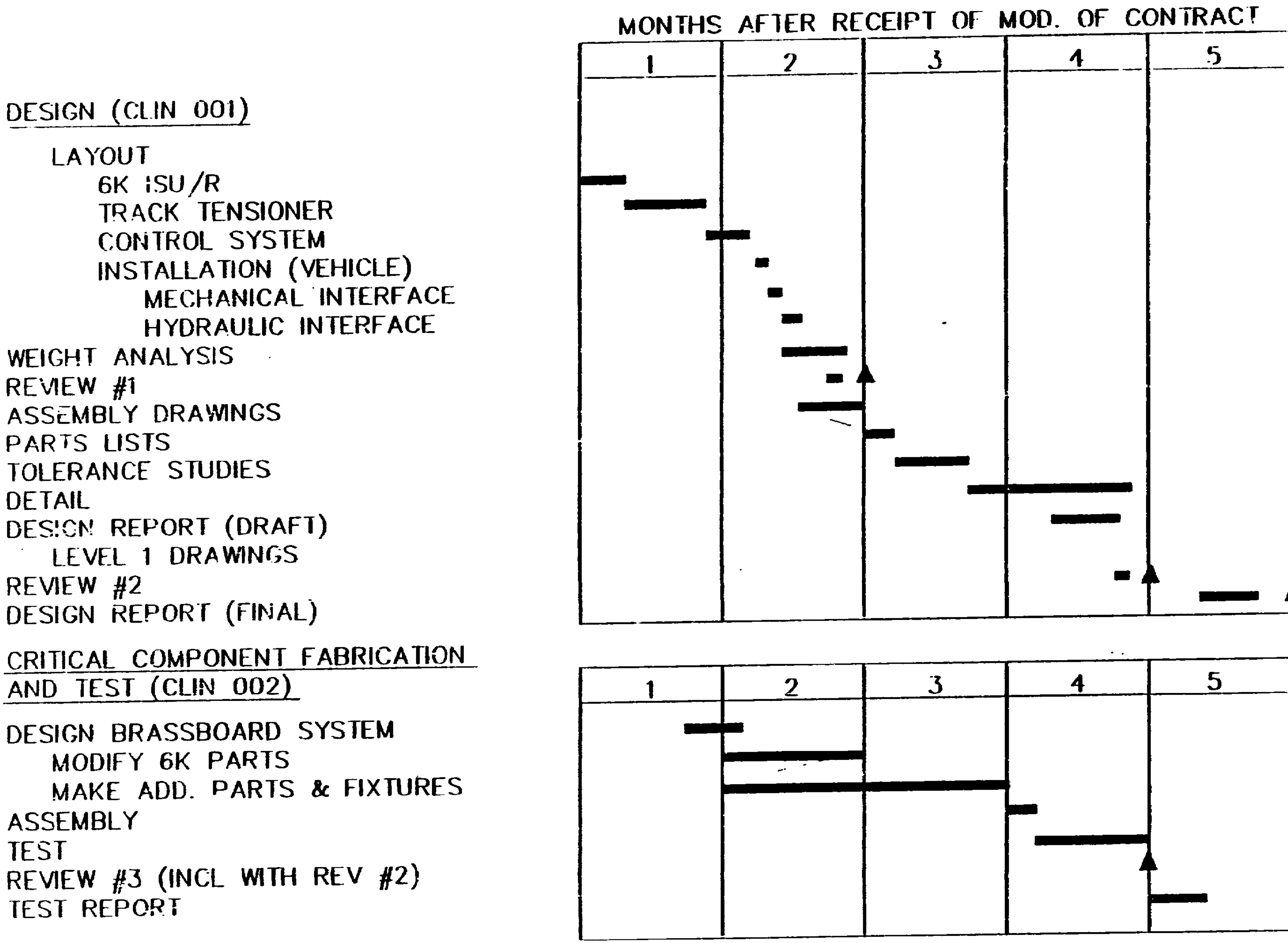

MONTHS AFTER RECEIPT OF MOD. OF CONTRACT
1
2
3
4
5
DESIGN (CLIN 001)
LAYOUT
6K ISU/R
TRACK TENSIONER
CONTROL SYSTEM
INSTALLATION (VEHICLE)
MECHANICAL INTERFACE
HYDRAULIC INTERFACE
WEIGHT ANALYSIS
REVIEW #1
ASSEMBLY DRAWINGS
PARTS LISTS
TOLERANCE STUDIES
DETAIL
DESIGN REPORT (DRAFT)
LEVEL 1 DRAWINGS
REVIEW #2
DESIGN REPORT (FINAL)
CRITICAL COMPONENT FABRICATION AND TEST (CLIN 002)
DESIGN BRASSBOARD SYSTEM
MODIFY 6K PARTS
MAKE ADD. PARTS & FIXTURES
ASSEMBLY
TEST
REVIEW #3 (INCL WITH REV #2)
TEST REPORT

FIGURE 4.

STATEMENT OF WORK

DESIGN EFFORT FOR RETRACTABILITY OF 6K ISU

BACKGROUND

The contractor shall perform a design effort to describe and detail required changes to make the current 6K ISU hydropneumatic suspension system fully retractable. This shall allow for full retraction of the suspension system, roadwheels, and tracks to be flush with the underside of a test vehicle. A report and Level I drawings shall be generated for this effort.

DESIGN EFFORT

The Contractor shall perform a system design to adapt the current 6K ISU system to be a fully retractable hydropneumatic suspension. This design shall utilize the currently as-designed and built in-arm hydropneumatic suspension system, striving to maximize use of current hardware. Adaptation and changing of parts is acceptable, including the increase in length of the roadarm housing.

An overall description of the hydropneumatic system shall be provided. This shall include an identification of key parameters such as operating pressures, roadwheel travel (rebound to static to jounce), damping rates, design loadings, structural safety factors, corrosion, etc.

INSTALLATION SPECIFICATIONS

The contractor shall detail the means by which the host vehicle would have to be modified to accept the retractable system, including mechanical and hydraulic interfaces required. A design shall also be generated for attaching the retractable suspension system to a generic vehicle utilizing 1.25 inch thick aluminum lower sidewalls and bottom plate and any additional requirements for mounting. The requirement for water tight integrity is mandated.

In adapting the suspension system, the Contractor is allowed to slightly intrude into the vehicles's interior space with the suspension units. Any such requirement of the hull for suspension installation shall be presented and shall assure the water tight integrity of the vehicle.

DESIGN CHARACTERISTICS

The Contractor shall develop a design for the retractable system to meet the characteristics listed below:

GROSS VEHICLE WEIGHT: 65,000 pounds maximum loaded (no 15% weight margin required)

TRACK TYPE: 21 inches wide
Single pin front sprocket drive,
50 pounds per foot of weight

MAXIMUM LAND SPEED: 45 mph

STATIC VEHICLE HULL CLEARANCE: 16 inches above ground

ROADWHEEL DIAMETER: 24 inches

SUSPENSION TRAVEL REQUIREMENTS

STATIC TO JOUNCE: 17 INCHES (all roadwheel stations)
STATIC TO REBOUND: 4 INCHES (all roadwheel stations)

SPRING CAPABILITY: 3.5 G capability (desired)
3.0 G capability (acceptable)

SUSPENSION DAMPENING - Same as base contract

DURABILITY - Same as base contract

MAINTENANCE - Same as base contract

SALT WATER CORROSION - Same as base contract

BALLISTIC PERFORMANCE - Same as base contract

NATURAL HEAVE AND BOUNCE FREQUENCY: Same as base contract

CORROSION PROTECTION: Same as base contract

TEMPERATURE EFFECTS: Same as base contract

DESIGN LOADS: Same as base contract

SUSPENSION PARTS AVAILABILITY: Same as base contract

MAINTAINABILITY: Same as base contract

TRACK CENTERLINE DISTANCE TO HULL: 12.625 INCHES

VEHICLE HYDRAULIC SYSTEM

The hydropneumatic suspension shall be compatible with 30 wt. hydraulic fluid used in the vehicle (as specified in the base contract Statement of Work). The contractor shall detail hydraulic requirements that need to be provided by the vehicle to retract the suspension system. Hardware unique to the suspension system shall be detailed and a weight estimate provided for. Required changes, modifications, or additions to the vehicles hydraulic systems shall be detailed.

WEIGHT

The weight of the hydropneumatic suspension unit, depicted from the vehicle hull attachment point up to, but not including the roadwheel, shall be detailed. The weights computed shall include roadarms, hydropneumatic suspension units, plumbing, suspension unique hydraulic components, track tensioner mechanism, and other components needed to make the suspension function. The roadwheels, idler, sprocket and track shall not be counted in the weight estimate. Commonality with the current system shall be maximized. A detailed breakout shall be provided, including weights of current hardware that is useable and weights of new components required.

TIME SCHEDULE

The Design process shall require no more than four (4) calendar months.

DESIGN REVIEWS

The contractor shall host two reviews at his facility during the course of this effort. Scheduling and dates will be determined. Review dates shall be at the approximate 50% and 100% completion points.

DESIGN REPORT

The Contractor shall prepare a Design Report (same format as CDRL A010) based upon the design and findings during this effort. The report shall be due 150 days after award of modification. Included in the report will be Level I Engineering and Associated Drawings (same as Sequence Number A001) for all major components of the suspension system, suspension units, and other components required. Two copies (reproduced copies are acceptable) of each pertinent drawing shall be provided at the Final Design Review.

PROGRESS REPORTING

Shall be reported in current Monthly Progress Reports (Sequence Number A015).

ENCLOSURE B

SPRING CURVE CALCULATIONS -
TEST UNIT

PISTON BORE :
DIAMETER (IN.)= 3.5
AREA (IN.^2)= 9.621119
CRANK PIN LOCATION :
X COORDINATE (IN.)= 1.004
Y COORDINATE (IN.)= 2.959
CONNECTING BAR LENGTH (IN.)= 9.262
ROADARM :
LENGTH (IN.)= 16
OFFSET (IN.)= 0
PSI (RAD.)= .1948 ALPHA (RAD.)= 0

REBOUND TRAVEL = 3.5
STATIC POSITION = -9.379
JOUNCE TRAVEL = 12.5

POSITION (IN.)	VOLUME (IN.^3)	STROKE (IN.)	D2 (IN.)	RW LEVER (IN.)	BETA (DEG.)
-4	63.34	0.81	2.384	9.494	-5.75
-3	61.00	0.56	2.530	10.719	-4.43
-2	58.77	0.33	2.653	11.732	-3.38
-1	56.63	0.11	2.758	12.586	-2.51
1	54.54	-0.11	2.847	13.310	-1.80
2	52.51	-0.32	2.923	13.926	-1.23
3	50.50	-0.53	2.986	14.446	-0.76
4	48.53	-0.73	3.037	14.881	-0.40
5	46.57	-0.94	3.077	15.238	-0.13
6	44.64	-1.14	3.105	15.523	0.05
7	42.72	-1.34	3.121	15.739	0.15
8	40.82	-1.53	3.124	15.889	0.17
9	38.94	-1.73	3.116	15.976	0.11
10	37.07	-1.92	3.094	16.000	-0.02
11	35.22	-2.12	3.058	15.961	-0.22
12	33.38	-2.31	3.008	15.859	-0.51
13	31.57	-2.50	2.942	15.693	-0.86

	STATIC	JOUNCE
ROAD WHEEL FORCES (LBS.)	6000	18000
PRESSURES (PSI)	2880	9978
PRESSURES (ATM.)	195.9184	678.7755
TEMPERATURES (DEG-K)	294	412.4191
DENSITY (MOLES/LITER)	7.726	13.602

NUMBER OF MOLES = 7.039506

RETRACT
DATE: 06-07-1991
TIME: 08:36:46

POSITION IN.	THETA DEG	VOLUME IN^3	DENSITIES MOLES/LITER	SPECIFIC VOLUME CC/MOLE
-3.5	-53.6	63.3	6.779	147.5
-2.5	-47.94	61	7.04	142
-1.5	-42.84	58.8	7.306	136.9
-.5	-38.13	56.6	7.583	131.9
.5	-33.71	54.5	7.873	127
1.5	-29.5	52.5	8.178	122.3
2.5	-25.46	50.5	8.503	117.6
3.5	-21.56	48.5	8.849	113
4.5	-17.75	46.6	9.22	108.5
5.5	-14.03	44.6	9.62	104
6.5	-10.37	42.7	10.051	99.5
7.5	-6.74	40.8	10.519	95.1
8.5	-3.15	38.9	11.028	90.7
9.5	.43	37.1	11.583	86.3
10.5	4.02	35.2	12.193	82
11.5	7.62	33.4	12.863	77.7
12.5	11.25	31.6	13.602	73.5

PISTON BORE :
DIAMETER (IN.)= 3.5
AREA (IN.^2)= 9.621119
CRANK PIN LOCATION :
X COORDINATE (IN.)= 1.004
Y COORDINATE (IN.)= 2.959
CONNECTING BAR LENGTH (IN.)= 9.262
ROADARM :
LENGTH (IN.)= 16
OFFSET (IN.)= 0
PSI (RAD.)= .1948   ALPHA (RAD.)= 0

REBOUND TRAVEL = 3.5
STATIC POSITION = -9.379
JOUNCE TRAVEL = 12.5

RETRACT
DATE: 06-07-1991
TIME: 08:37:02

POSITION (IN.)	SIDE FORCE (LBS)	C BAR FORC (LBS.)	TEMP. (DEG-K)	PRES. (PSI)	RW. (LBS)	TORQUE (IN.-LBS)
-4	-2136	21331	270	2206	5356	50833
-3	-1770	22890	276	2372	5403	57919
-2	-1446	24548	282	2547	5551	65133
-1	-1155	26349	288	2736	5773	72671
1	-892	28319	294	2942	6058	80636
2	-652	30467	300	3166	6395	89060
3	-438	32869	306	3416	6794	98154
4	-249	35532	313	3693	7252	107924
5	-91	38889	321	4042	7852	119654
6	36	42843	331	4453	8568	133011
7	122	47144	340	4900	9347	147116
8	153	52002	349	5405	10225	162480
9	114	58083	361	6037	11328	180975
10	-21	65674	375	6826	12700	203197
11	-292	74680	389	7762	14310	228401
12	-754	85439	404	8830	16205	257004
13	-1487	98647	421	10252	18493	290212

RETRACT
DATE: 06-07-1991
TIME: 08:37:07

ENCLOSURE C

DETAILED WEIGHT ESTIMATION - CONCEPT DESIGN SYSTEM

SUSPENSION UNIT

DESCRIPTION	WEIGHT, LBS
Spindle, Roadarm	53.40
Spindle, Wheel, Vehicle	7.56
Pin, Spindle, Torque	0.39
Piston, Actuator	8.15
Cap, Piston, Actuator	0.57
Bearing, Connecting Bar	0.27
Ring, Retainer, Connecting Bar	0.04
Connecting Bar Assembly	4.90
Ring, Glyd	0.04
Seal, Piston, Actuator	0.02
Ring, Expansion, Actuator Piston	0.30
Spring, Compression Seal	0.05
Ring, Spacer	0.17
Spacer, Seal	0.43
Valve, Oil Fill	1.60
Diaphragm, Accumulator	0.20
Cover, Accumulator	3.12
End Cap, Accumulator	3.67
End Cap, Roadarm	5.32
Screw, Valve	0.07
Stem, Valve	0.02
Plug	0.02
Screw, Cap, Hex Head	0.02
Screw, Cap, Hex Head	0.06
Screw, Flat Head, Hex Socket	0.08
Cam, Pump	1.39
Screw, Cap, Hex Head	0.01
Roadarm	109.80
Cover, Torque	19.22
Plug, Hollow Hex, O-ring	0.02
Plug and Bleeder	0.02
Pin, Drive	0.35
Retainer, Bearing	2.24
Shim, Bearing Retainer	0.26
Piston, Damper	3.01
Ball, Check Valve	0.10
Spring Guide, Check Valve	0.05
Seat, Check Valve	0.08
Spring, Check Valve	0.02
Seal, Crankcase Oil	0.01
Seal, Connecting Bar	0.01
Pin, Connecting Bar	1.58
Disc, Stator Assembly	1.69
Disc, Rotor	5.51
Race, Inner	0.05
Race, Outer	0.05
Piston, Pump	0.24
Retainer, Damper	7.21
Stator, Damper	2.44
Spool, Relief Valve	0.07
Sleeve, Relief Valve	0.36
Spring, Relief Valve	0.02
Spring Guide, Relief Valve	0.01
Screw, Cap, Hex Head	0.05
Sleeve, High Pressure	7.42

DESCRIPTION	WEIGHT, LBS
Sleeve, Retraction	5.57
Cover, Charge Valve	0.43
Screw, Socket Head	0.01
Spring, Damper	0.35
Sleeve, Piston	2.58
Pin, Stator	0.05
Hub Assembly, Roadwheel	24.84
Fluid	7.00
TOTAL UNIT WEIGHT	307.47

TRACK TENSIONER

DESCRIPTION	WEIGHT, LBS
Sleeve, Housing	27.23
Piston, Outer	11.40
Piston, Inner	17.49
Bushing, Pin	1.75
Pin, Pivot	6.53
Cap, Pin	.62
Bracket, Tensioner	18.09
Housing, Bearing	4.85
Bearing, End Cap	1.26
Screw, Bracket	1.37
Fluid	0.40
TOTAL UNIT WEIGHT	90.99

CONTROL SYSTEM

DESCRIPTION	WEIGHT, LBS
Cycle Valve	3.50
Control Valve	3.50
Pressure Switch	2.50
Accumulator	13.00
Check Valve (24)	10.00
Manual Valve	4.00

DESCRIPTION	WEIGHT, LBS
Tubing	21.00
Fittings	5.00
Limit Switches	3.00
Manifold	30.00
Fluid	0.70
TOTAL SYSTEM WEIGHT	96.20
INTENSIFIER UNIT WEIGHT	20.00

ENCLOSURE D

TEST PLAN

6K ISU MODIFIED FOR RETRACTION
DEVELOPMENT TEST PLAN

1.0 PURPOSE

The purpose of this plan is to define the test procedure used in demonstrating the principle of a retractable hydropneumatic suspension unit for use on tracked military vehicles.

2.0 UNIT DESCRIPTION

The test specimen is a current production 6K ISU modified to incorporate the retraction feature.

3.0 PRE-TEST INSPECTION

3.1 Dimensional

All new and modified parts are to be dimensionally inspected and recorded.

3.2 Photographs

All new and modified parts are to be photographed for record purposes.

4.0 ASSEMBLY

All parts shall be cleaned per Cadillac Gage cleaning procedure and assembled in a clean environment. CAUTION: The roadarm is not to be allowed to travel below the 3.5 inch rebound position. This would result in damage to the internal components.

5.0 TEST PROCEDURE

5.1 Proof Pressure

5.1.1 Spring Cavity

The unit shall be fully assembled except the gas spring cavity shall be filled with oil. Apply an external load to the wheel spindle of the unit at the jounce position such that the pressure in the gas cavity raises to 15,000 psig. Maintain this pressure for 5 minutes. There shall be no evidence of leakage of permanent distortion.

5.1.2 Retraction Cavity/Control Valve

With the spring cavity filled with oil and the unit at the jounce position, pressurize the retraction cavity until the pressure raises to 19,000 psig. Maintain this pressure for 5 minutes. There shall be no evidence of leakage or permanent distortion. The control valve is to be pressurized to 19,000 psig and held for 5 minutes. There shall be no evidence of leakage or permanent distortion.

5.2 Retraction Component Proof Load

With the gas spring cavity vented to atmospheric and the unit in the jounce position with further upward movement restricted, apply a pressure of 1,830 ±20 psig to the retraction cavity and hold for 5 minutes. There shall be no evidence of permanent distortion in the components.

5.3 Retraction Operation

5.3.1 Retract

While applying pressure to the retraction cavity, measure and record the pressure of the retraction cavity, wheel position, gas spring pressure, and damping pressure from -3.5 inches spindle location to +12.5 inches spindle location. This retraction operation is to be accomplished in approximately 3 minutes. This position to be held for one hour.

5.3.2 Extend

While releasing the pressure to the retraction cavity, measure and record the pressure of the retraction cavity, wheel position, gas spring pressure, and damping pressure from +12.5 to -3.5 inch spindle location. This operation to be accomplished in approximately 30 seconds.

5.3.3 Retraction Operation Repeat

Paragraphs 5.3.1 and 5.3.2 to be repeated twenty times.

5.3.4 Video Tape

Three retraction and three extend operations are to be video taped and provided to DTRC with the final report.

5.3.5 Leak Test Cycle

Upon completion of Paragraph 5.3.3, the unit is to be retracted, the intensifier blocked from the system, and the tank port of the control valve vented to atmosphere. This retraction mode to be held for one hour. Measure and record the pressure of the retraction cavity, wheel position, gas spring pressure, and leak rate from control valve.

Upon completion, open the control valve and allow the unit to extend to the rebound position. Measure and record the pressure of the retraction cavity, wheel position, and gas spring pressure.

Prior to disassembly for inspection, the fluid in the spring and crankcase is to measured and recorded.

5.4.1 Visual Inspection

All parts shall be visually inspected.

5.4.2 Dimensional Inspection

All new and modified parts are to be dimensionally inspected and measurements recorded.

5.4.3 Summary

A summary of the inspection shall be made to include any change in appearance or dimension of parts.

United States Marine Corps
Amphibian Vehicle Test Branch
Camp Pendleton, California 92055-5080

8410/89020C
AVTB-6
23 JAN 91

From: Head, Amphibian Vehicle Test Branch, Camp Pendleton, CA
To: Program Manager, Advanced Amphibious Assault, Marine Corps Research, Development and Acquisition Command

Subj: INTERIM TEST REPORT ON THE HYDROPNEUMATIC SUSPENSION SYSTEM (HSS) FOR THE AAV7A1 FAMILY OF VEHICLES

Ref: (a) Program Manager, Advanced Amphibious Assault, ltr ser 409/MOB of 26 Sep 90

Encl: (1) Advanced Demonstration Test Plan for a Hydropneumatic Suspension System (HSS) mounted on an Assault Amphibian Vehicle (LVTPX-12) of 6 Aug 90

1. In this Interim Report and in accordance with the reference, AVTB has summarized the results of HSS Testing since the restart of the program 27 Apr 90. The enclosure is the guiding document for testing and is included for informational purposes.

2. The following is an overview of the major results, conclusions and recommendations at this point in HSS testing.

3. Ride Quality: Subjectively, the HSS equipped vehicle (HSS/AAV) provides a smoother ride than the standard AAV. AVTB has not collected sufficient hard data to verify this contention.

4. Vehicle Land Speed: The HSS/AAV is slower than the standard AAV when traveling over packed sand and pavement.

5. Water Operations/Amphibious Shipping: HSS does not negatively impact surf transit, water operations or amphibious shipping capabilities of the AAV. However, as a maintainability concern, the return (support) roller hubs were constantly being contaminated by water operations.

6. Maintainability:
   a. Because oil and nitrogen leaks occur whether the vehicle is operating or sitting idle, checking and adjustment are required at much shorter intervals than indicated in the test plan.

   b. The HSS unit crankcase seals are destroyed by dirt, water and the resulting corrosion.

   c. In some cases, the dowel pins in the HSS hull flanges have backed out of the flanges. This reduces the ability of the HSS unit-to-hull connection to resist the torque of normal suspension action.

d. The HSS units cannot be removed or installed in the pressurized condition; which means the maintenance cart must be present to pressurize the units after installation.

e. The HSS units are extremely difficult to install without the crane on the maintenance cart.

f. The track cannot be connected unless the #2 HSS unit is unpressurized.

7. Conclusions: The HSS in its current configuration is a failure due to its negative impact on vehicle land speed and on vehicle maintainability.

8. Recommendations: Further testing of the current HSS configuration will be very difficult as AVTB has no more spare rebuilt units and most of the units currently installed are leaking both oil and nitrogen.

The HSS concept holds promise for eventually improving cross country ride quality and speed. However, to reduce the maintainability problems and improve the vehicle ride height response to changing vehicle weights, the next HSS effort should concentrate on an active or so-called "smart" suspension with on-board sensors, microprocessors and compressors which would continuously monitor and adjust suspension characteristics to compensate for changing speed, environmental and weight conditions.

J. M. MERRIETT III

Subj: INTERIM TEST REPORT ON THE HYDROPNEUMATIC SUSPENSION SYSTEM (HSS) FOR THE AAV7AI FAMILY OF VEHICLES

1.0 PURPOSE: The purpose of this document is to provide information on the results of HSS Testing from the restart of testing 27 April 1990, through 15 November 1990.

2.0 BACKGROUND: HSS Testing on the PX1210 vehicle originally began on 3 November 1989. Because of a tendency for the suspension units to remain in the retracted position, the vehicle was shipped back to the contractor for rework of the shock absorber fluid orifices on 4 January 1990. After returning to AVTB, the vehicle was equipped with an Enhanced Applique Armor Kit (EAAK). Testing was restarted on 27 April 1990, and all previous test results were invalidated.

3.0 TEST TYPES, PURPOSES, METHODS AND RESULTS:

3.1 RIDE QUALITY; The ability of a tracked vehicle to transit cross country terrain without degrading embarked troop performance is paramount to the mobility and survivability of the FMF.

3.1.a PURPOSE. Testing of this system parameter shall provide a quantification of the ride quality that this system possesses versus a conventional AAV with a torsion bar/shock absorber suspension system.

3.1.b METHOD. A test matrix should be established to measure Input Power Levels taken for the following variations in vehicle configuration:

(1) Measurements taken on the modified AAV/HSS versus Baseline AAV7A1.

(2) Measurements taken at Troop Compartment floor and Driver's Position.

(3) Measurements for vehicle weight conditions A and B (53,500 and 58,100 pounds)

Over a set terrain profile to be established at AVTB, the different test configurations will be run with the dual accelerometer data of input power levels being recorded. The vehicles shall enter and maintain pre-determined speeds in the test profile. Each test duration shall be of 2 minutes or less.

3.1.c RESULTS. The ride quality instrumentation provided to AVTB was inoperable and inadequate. AVTB is developing its own ride quality instrumentation and data collection capability which will be used in subsequent testing.

Two sets of instrumentation will be used so that the HSS/AAV and the standard AAV can be run simultaneously at identical speeds and over identical terrain paths. This will provide a true comparison between the input power levels.

3.2 <u>CROSS COUNTRY TEST COURSE TRANSIT TIME</u>: The survivability and mobility of a tracked combat vehicle is dependent on its ability to transit cross country terrain in the shortest possible time, within the human and vehicle limits of absorbing terrain induced loads.

3.2.a <u>PURPOSE</u>: This test shall provide data on the time required and comparability of different suspension equipped vehicles to transit cross country terrain, allowing the vehicle driver's endurance and tolerance limits to dictate speed and time required for transitting the course.

3.2.b <u>METHOD</u>: The modified and baseline vehicles shall be operated over a cross country test course established at AVTB. Minimum time required to transit the course shall be recorded for each vehicle. Interim times shall be measured through sections of the course dependent on terrain to be crossed (sandy, hill climb/descent, washboard, etc.).

Two vehicles shall be used: a baseline AAV (with no other suspension test components) and the AAV/HSS. Two vehicle crews (total of four different drivers) shall be utilized, taking turns driving each vehicle, twice in each direction, through the test course. The drivers shall operate the vehicles at safest maximum possible speed.

Tests should be conducted for both weight conditions. No other test instrumentation is required.

3.2.c <u>RESULTS</u>: This test has not been conducted.

3.3 <u>AMPHIBIOUS COMPATIBILITY</u>: Force projection and amphibious deployments are required attributes for USMC tracked amphibious vehicles. All systems utilized on this type vehicle must be compatible with amphibious shipping and surf operations.

3.3.a <u>PURPOSE</u>: The ability to embark and disembark amphibious shipping shall be demonstrated to validate compatibility with normal vehicle operations. Secondly, the vehicle must be able to operate within and transit the surf zone.

3.3.b <u>METHOD</u>: In conjunction with other AAV amphibious ship operations, the AAV/HSS shall embark and disembark amphibious ships when the opportunity is made available.

The vehicle shall be tested at weight conditions A and B. Weight condition A is the first test priority.

It shall be attempted to embark and disembark the ship at each weight condition three times.

The vehicle shall be operated, parked and secured in different ship areas to evaluate compatibility and safety concerns, including "dogging down" of vehicle for the duration of a Fire Watch period.

The vehicle shall be water towed and recovered (with track intact) onto amphibious shipping.

The vehicle should be operated in the surf zone (to safe and maximum extent possible, high surf desired) in conjunction and commensurate with other AAV surf operations.

3.3.c **RESULTS**:

(1) PX1210 weighted to 58,100 pounds successfully embarked and disembarked an LST ballasted to 18 feet with a ramp angles of 11 degrees.

(2) PX1210 weighted to 58,100 pounds was "dogged down" in the LST for 13 hours. The results indicate that the HSS/AAV is not negatively impacted by this procedure. Vehicle heights were as follows:

		PORT	STBD
Before dogging	Forward	13 1/4"	13"
	Aft	17"	17"
After dogging	Forward	10 1/2"	10"
	Aft	17"	17"
After undogging	Forward	13"	12"
	Aft	17"	17"
Vehicle moved 20 feet	Forward	13 1/4"	13"
	Aft	17"	17"

(3) The only towing test was conducted through the surf zone with PX1210 successfully towing an AAVP7A1 stern to bow and stern to stern.

(4) Surf operations included 3 successful outbound and inbound transits of the surf zone. Wave height was less than 6 feet.

3.4 **VEHICLE HANDLING COMPARISON TESTS**: All changes and improvements to the AAV family must be done so without sacrificing or degrading current vehicle performance.

3.4.a **PURPOSE**: Comparative testing of the operation and handling qualities of this modified vehicle versus a standard

Note: Because the standard AAV at 58,070 pounds only achieved 28.0 mph maximum speed, the elapsed time for the HSS/AAV at 58,100 pounds to reach 28.0 mph is listed for comparison.

The results are inconsistent in that the HSS/AAV had greater acceleration at the heavier weight condition while the standard AAV lost acceleration. The loss of acceleration with increasing vehicle weight would be the normal expectation.

(2) AVTB conducted panic stop tests on a paved road at both weight conditions on the HSS/AAV and the standard AAV. The test series at 58,100 pounds was conducted first with skidding of the vehicle allowed. In reviewing the video tapes of this test it was noticed that the final drives of the standard AAV were contacting the road surface. The HSS/AAV burned its brakes after 6 panic stops. When the test was repeated at 53,500 pounds, the definition of a panic stop was refined to stopping as rapidly as possible without skidding the vehicle. Also, a cooling down period of 20 to 30 minutes with engine idling was scheduled between test runs. The following is a summary of 30-0 mph panic stop braking distances:

Vehicle	Weight	Average Braking Distance	Force on Brake Pedal	Speed at Brake Application	Number of Runs Averaged	Direction of Run (N to S is slightly downhill)
HSS/AAV	53,500	56.5 Feet	188 lbs	29.9 mph	4	N to S
AAV	53,500	68.4 Feet	175 lbs	30.6 mph	4	N to S
HSS/AAV	58,100	65.3 Feet *	Transducer Broken	Not Recorded	6	N to S
AAV	58,100	49.5 Feet	Transducer Broken	Not Recorded	6	N to S

* Brakes failed on seventh test run

The results indicate that at the lighter weight condition the HSS/AAV stops more quickly than the standard AAV. Because the brakes on the HSS/AAV were in the process of failing during the heavier weight tests, comparing braking distances is questionable. It was clear, however, that the HSS/AAV stops in a more controlled manner as far as forward pitching is concerned, especially when the vehicle's tracks are locked in a skid.

(3) Attempts at performing a slalom test on packed dirt have proven to be difficult because of the problem with maintaining a constant speed while turning. The vehicle's drive train causes a loss of engine speed proportional to the degree of steering input. The tight turns, steering corrections

tative and quantitative.

3.4.b **METHOD**: The following tests shall be performed with the vehicle in weight condition A and video coverage shall document vehicle operations:

(1) Accelerate the vehicle from 0 - 30 mph on a hard surface.

(2) Decelerate the vehicle, in a panic stop mode, from 30 mph to a stop on a hard surface.

(3) Operate the vehicle through a slalom course that provides 0.3g, 0.5g and 0.7g turns at 10, 20 and 30 mph on a packed dirt/hard surface.

(4) Operate the vehicle in the boat basin adjacent to AVTB and in the surf zone of Camp Pendleton beaches with waves up to 6 feet high.

(5) All of the above conditions shall be repeated at weight condition B.

(6) Equivalent testing shall be performed with the baseline AAV7A1 at equivalent weight conditions.

3.4.c **RESULTS**:

(1) AVTB conducted acceleration and top speed tests on a paved road at both weight conditions on the AAV/HSS and at 53,500 pounds on the standard AAV vehicle. Results from previous Enhanced Applique Armor Kit (EAAK) Testing with a 10,000 pound cargo load (58,070 pounds total) will be used for 58,100 pound data on the standard AAV vehicle. The following is a summary of 0 - 30 mph acceleration times and top speeds:

Vehicle	Weight	Number of Runs Averaged	Direction of Run (N to S is slightly downhill)	Average Elapsed Time 0-30 MPH	Average Maximum Speed Attained
HSS/AAV	53,500	4 Runs	N to S	30.8 Sec	Not Recorded
AAV	53,500	4 Runs	N to S	26.7 Sec	Not Recorded
HSS/AAV	58,100	4 Runs	N to S	26.7 Sec	41.1 mph
AAV	58,070	1 Run	N to S	30.2 Sec	43.0 mph
HSS/AAV	53,500	Not Conducted	S to N	--------	------------
AAV	53,500	Not Conducted	S to N	--------	------------
HSS/AAV (See Note)	58,100	2 Runs	S to N	74.0 Sec (62.0 Sec)	32.0 mph (28.0 mph)
AAV	58,070	3 Runs	S to N	44.8 Sec	28.0 mph

and direction changes of the current standard test procedure (see Annex A) make achieving and maintaining a smoothly alternating G-Force on the vehicle almost impossible. The requirements at 30 mph were deleted as the AAV/HSS could not achieve this speed. Also, the slalom course length was reduced by half because of size limitations at the Camp Pendleton test site. The results of AVTB's slalom testing are summarized in the following:

Vehicle	Weight	Target Speed	Target G-Force	Radius of Turn	Actual Speed	Actual G-Force
HSS/AAV		10 mph	0.5	13.36 Feet	2 - 14 mph	0.0 - 0.5

The inability to maintain the test parameters of constant speed and G-Force caused postponement of further testing.

(4) The HSS/AAV has been successfully operated in the boat basin and through surf less than 6 feet high. Surf heights of 6 feet or greater have not been available at Camp Pendleton. A smooth water top speed has not been measured.

3.5 __BASELINE VEHICLE REQUIREMENTS__: New improvements and changes must not prevent the vehicle from performing to its original design specifications. This series of testing will validate that the HSS/AAV vehicle still meets the baseline requirements of the AAV7A1, as detailed in the Developmental Testing III (DT-III) Test Requirements.

3.5.a __TRENCH CROSSING TEST__

3.5.a.1 __PURPOSE__: To demonstrate that the test vehicle can cross a trench up to four feet deep and eight feet wide.

3.5.a.2 __METHOD__:

(1) Add weights to the test vehicle to achieve 53,500 pounds.

(2) Slowly drive the test vehicle over the required eight foot wide by four foot deep trench.

(3) Document the test with video or still photography, as appropriate.

(4) Repeat for test vehicle weight of 58,100 pounds.

(5) Repeat for baseline AAV7A1 at equivalent weights.

3.5.a.3 **RESULTS**:

(1) AVTB utilized an earthen trench for this test which measured approximately 8 feet wide by 4 feet deep.

(2) The HSS/AAV and the standard AAV successfully traversed the trench at both 53,500 and 59,000 pounds.

3.5.b **VERTICLE OBSTACLE TEST**:

3.5.b.1 **PURPOSE**: The purpose of this test is to demonstrate that the test vehicle can scale a 36 inch verticle obstacle.

3.5.b.2 **METHOD**:

(1) Add weights to the test vehicle to achieve 53,500 pounds.

(2) Slowly drive the vehicle over the required 36 inch verticle obstacle.

(3) Document the test with video or still photography as appropriate.

(4) Repeat for test vehicle weight of 58,100 pounds.

(5) Repeat for baseline AAV at both weights.

3.5.b.3 **RESULTS**:

(1) AVTB utilized the verticle end of a concrete truck loading ramp that is exactly 36 inches high for this test.

(2) The HSS/AAV and the standard AAV successfully traversed the verticle obstacle at both 53,500 and 59,000 pounds.

3.5.c **CORROSION**:

3.5.c.1 **PURPOSE**: The purpose of this observation is to determine any areas of the test items that are susceptible to corrosion.

3.5.c.2 **METHOD**:

(1) During testing, observe, analyze and record suspension failures suspected of being due to corrosion.

(2) Observe and report any areas suffering corrosion effects.

3.5.c.3 **RESULTS**:

(1) According to the Cadillac Gage Textron Status Report of 15 May 1990, contaminant intrusion and rust formation at the primary oil seal, with the resultant deterioration of the seal, are allowing the external leakage of the fluid and nitrogen gas pressure from the suspension unit's crankcase. At the last check of crankcase pressures on 18 Oct 1990, nine of the twelve units had lost all crankcase pressure. Of these nine, three units would not hold pressure after being recharged.

(2) The low pressure protection plug hex socket fills with rust and must be removed with a pipe wrench.

(3) The roadwheel hub oil fill/drain plugs tend to seize in the threads and then the hex socket gets stripped during removal attempts.

(4) The crankcase cover bolts and locking tabs are rusting.

(5) The high pressure bleed/fill port cover and the bolts which hold it are rusting. The screws are being replaced with stainless steel screws during pressure checks. In one case, the plugs under the cover were badly rusted.

3.5.d **CLIMATIC TESTING**:

3.5.d.1 **PURPOSE**: The purpose of this test phase is to identify any aspects of the test items (or test vehicle installation) that are susceptible to improper operation during extremes in ambient operating temperatures.

3.5.d.2 **METHOD**: It is recommended that the vehicle and operation/maintenance crew be deployed to test regions where 500 miles of hot desert testing (100° to 125°F) and 500 miles of arctic testing (-25° to 0°F) can be accumulated during the time period. During testing, observe, analyze and record suspension failures suspected of being due to the environment. Observe and report any operational aspects suffering environmental effects. Conduct of baseline testing shall be accomplished to the maximum extent possible.

During this testing, vehicle weight should be varied among weight conditions A and B for the recommended percentages of operating time. Any adverse or beneficial impacts to vehicle performance as a result of weight changes should be noted.

Added to this explanation of test methods for climatic testing is the following excerpt from page 4 of the 6 Aug 1990, HSS Test Plan:

Hot Weather Testing

Ride Quality	Test 3.3.1
Cross Country Test Course	Test 3.3.2
Vehicle Handling Comparison	Test 3.3.4
Baseline Vehicle Requirements	Test 3.3.5 (a, b, e, f)
Design Requirements	Test 3.3.6 (a, b, c, d, e)
RAM-D Tests (500 Miles)	Test 3.3.7

3.5.d.3 **RESULTS:**

(1) Hot Weather Testing: AVTB conducted hot weather testing at several desert sites at the Twentynine Palms Marine Corps Base from 18 Aug 1990 to 10 Sep 1990. Temperatures exceeding 100°F were inconsistent. Logistical support was difficult because of the heat, the rugged terrain and the distance from AVTB. Sharp, fist-sized rocks and the overall ruggedness of the terrain were hard on the final drives and suspension components of both the HSS/AAV and the standard AAV. The HSS/AAV logged 171 miles and 19 hours during hot weather testing. The standard AAV achieved 191 miles and 16 hours. The following is a summary of the hot weather test results.

(a) Ride Quality: Data was taken for the HSS/AAV at 53,500 pounds, but no comparison data was taken on the standard AAV because of interfering test events. Therefore, the data taken is meaningless.

(b) Cross Country Test Course: The only observation is qualitative; the drivers who drove both vehicles over the desert cross country course stated that the HSS/AAV provided a smoother, more controlled ride than the standard AAV.

(c) Vehicle Handling Comparison Test: The only desert testing done from this category was an attempt at slalom testing.

(d) Baseline Vehicle Requirements: None of these tests were conducted in the desert.

(e) Design Requirements: Fluid and gas level checks; the following is a list of the fluid and gas level checks made during hot weather testing:

Vehicle Weight	Position	Pressure Before	Pressure After	Oil Added	Miles Since Last Check
58,100	Stbd #2	0 PSI	3560 PSI	0	0
58,100	Stbd #2	2925	3380		13.5
53,700	Stbd #6			1 oz	
53,700	Stbd #6			1 oz	
53,700	Port #3			1 oz	
53,700	Stbd #1	3045	3245		
53,700	Stbd #2	2685	3245		
53,700	Stbd #3	1665	1975		
53,700	Stbd #4	695	1975		
53,700	Stbd #5	1310	1975		
53,700	Stbd #6	1420	1975	1 oz	
53,700	Port #1	2140	3245		
53,700	Port #2	2710	3245		
53,700	Port #3	1845	1975	1 oz	
53,700	Port #4	1740	1975		
53,700	Port #5	1825	1975		
53,700	Po t #6	1700	1975		

These results plus numerous daily log entries noting oil seepage from the low pressure crankcase cover indicate both low and high pressure sealing problems with HSS.

Ride Height; the following is a list of the vehicle height measurements taken during hot weather testing:

Vehicle Weight (pounds)	Location of Measurement (@ hull plugs)	Height Port	Height Stbd	Ambient Temperature	Measured after Cool-down	Measured after Operating
58,100	Forward	17 In.	16.5 In		X	
	Aft	14.75	14.75		X	
58,100	Forward	17	16.5	100°F		1.3 hrs, 11.3 mi.
	Aft	14.75	14.75	100°F		1.3 hrs, 11.3 mi.
58,100	Forward	17	16.5		X	
	Aft	14	14		X	
58,100	Forward	17	16.5	100°F		1.7 hrs, 13.5 mi.
	Aft	14	14	100°F		1.7 hrs, 13.5 mi.

Vehicle Weight (pounds)	Location of Measurement (@ hull plugs)	Height Port	Height Stbd	Ambient Temperature	Measured after Cool-down	Measured after Operating
53,700	Forward	18.5	18			.8 hrs, 7.3 mi.
	Aft	17	17			.8 hrs, 7.3 mi.
53,700	Forward	18.5	18	98°F		1.5 hrs,14.6 mi.
	Aft	17	17	98°F		1.5 hrs,14.6 mi.
53,700	Forward	17	16.75	83°F	X	
	Aft	14.5	14.5	83°F	X	
53,700	Forward	17.5	17.5	98°F		
	Aft	14.5	17.5	98°F		
53,700	Forward	17.5	18	88°F	X	
	Aft	14	14	88°F	X	
53,700	Forward	17.5	19.5	98°F		
	Aft	16.5	17	98°F		
53,700	Forward	18.5	17	95°F	X	
	Aft	15.5	14	95°F	X	
53,700	Forward	11	15	92°F	After Re-charging	
	Aft	19.5	22	92°F	Stbd Side Units	
53,700	Forward	14	15	82°F	X	
	Aft	18.5	20.5	82°F	X	
53,700	Forward	11	15	92°F	X	
	Aft	19.5	22	92°F	X	
53,700	Forward	16.5	16	89°F	After Re-charging	
	Aft	18	18	89°F	Port Side Units	

This tabulation indicates, as would be expected, that the ride height increases due to ambient and/or operational temperature increases are greater at the lower vehicle weight. Note the effect of recharging all the units at the lower weight, the aft end is higher than the forward end.

Return Roller Wear; the roller hubs reached 130°F when operating at 100°F ambient. There were no roller failures during hot weather testing.

Roadwheel/Suspension Unit Interference; after the HSS/AAV returned from hot weather testing, it was noted that all the units exhibited abrasion of the crankcase cover and cover bolt heads where the inner roadwheel runs next to the crankcase cover.

Track Tension Setting and Adjustment; by the end of hot weather testing the track tension adjusters had been extended to their recommended travel limits in order to maintain the 1/2 inch space between the track and the skid plate on each side of the HSS/AAV at the number 3 roadwheel position.

(2) COLD WEATHER TESTING; AVTB has not conducted any cold weather testing of the HSS/AAV.

3.5.e **SLOPE NEGOTIATION**:

3.5.e.1 **PURPOSE**: The purpose of this test is to determine the ability of the test vehicle to negotiate and maneuver on forward and side slopes safely.

3.5.e.2 **METHOD**:

(1) Place the test vehicle in weight condition A.

(2a) Operate the vehicle on forward slopes up to and including 60% inclines. The vehicle should be operated in forward and reverse.

(2b) Operate the vehicle on side slopes up to and including 40% inclines.

(3) Document the test with video or still photography as appropriate.

(4) Repeat for vehicle weight condition B.

(5) Repeat for baseline AAV7A1 at equivalent weights.

3.5.e.3 **RESULTS**: Both the HSS/AAV and the standard AAV successfully negotiated all segments of this test phase at both weight conditions.

3.5.f **PIVOT STEERING**:

3.5.f.1 **PURPOSE**: The purpose of this test phase is to determine the ability of the test vehicle to pivot steer during land operations, as the baseline AAV7A1 is able to do.

3.5.f.2 **METHOD**:

(1) Inspect and adjust the HS-400-3

transmission for full pivot steer capability.

(2) Pivot steer the vehicle on varied terrains (hard surface, secondary roads, packed sand, vegetated terrain) during the course of vehicle operations and RAM-D mileage accumulation. The vehicle should be steered left and right at various speeds at the two weight settings.

(3) Document the test with video or still photography, as appropriate.

3.5.f.3 **RESULTS**: The following is a tabulation of the rotation rates for the HSS/AAV on various terrains. Note that due to environmental concerns, vegetated terrain is not available at Camp Pendleton for tests which damage the vegetation.

Vehicle Weight	Terrain	Rotation Pace	Rotation Rate Left	Rotation Rate Right
53,500	Hard	Fast	12.5 Sec	13.9 Sec
	Surface	Slow	30.5	23.7
58,100	Hard	Fast		
	Surface	Slow		
53,500	Secondary	Fast	16	17
	Road	Slow	20	36
58,100	Secondary	Fast		
	Road	Slow		
53,500	Packed	Fast		
	Sand	Slow		
58,100	Packed	Fast		
	Sand	Slow		

3.5.g **MINE PLOW EVALUATION**:

3.5.g.1 **PURPOSE**: With future introduction and fitting of the mine plow to AAV's, this large weight mass at the nose of the vehicle and the push loads to be transmitted to the suspension system need to be investigated. This test is not to be an all-inclusive test, but a first look at identifying possible interface and operational problems.

3.5.g.2 **METHOD**: Following sufficient testing of the mine plow on a baseline AAV7A1, the plow shall be installed on the HSS/AAV. This shall be performed for a vehicle weight condition of 6,000 pounds of cargo in the troop compartment.

(1) The vehicle with mine plow and 6,000

pound cargo load shall be weighed and the LCG determined.

(2) The suspension contractor may provide new suspension unit pressures for the vehicle configuration to retain acceptable ground clearance. The nitrogen charge levels may be adjusted with new pressure settings.

(3) The vehicle with mine plow shall be operated and terrain plowed to evaluate impact on the suspension system.

3.5.g.3 **RESULTS**: AVTB has not conducted any testing of the mine plow in conjunction with the HSS/AAV.

3.5.h **NOISE MEASUREMENT**:

3.5.h.1 **PURPOSE**: Utilization of new components on the vehicle need to be evaluated for determination of whether they add to the acoustic signature of the vehicle.

3.5.h.2 **METHOD**: In accordance with procedures performed by AVTB to measure internal and external noise levels of other add-ons to the AAV7A1, similar efforts shall be employed to measure the levels for the HSS/AAV vehicle configuration.

This shall be performed for weight conditions A and B, and for the four listed terrain types:

- Paved Road
- Loose Sand
- Packed Sand
- Secondary Road

3.5.h.3 **RESULTS**: AVTB has not conducted any noise level testing of the HSS/AAV.

3.6 **DESIGN REQUIREMENTS**: All new systems undergoing evaluation should be monitored to validate proper functioning. Ride height and hydraulic/nitrogen levels in the suspension units are paramount to proper functioning.

3.6.a **FLUID AND GAS LEVEL CHECK**:

3.6.a.1 **PURPOSE**: To determine that the nitrogen and hydraulic oil levels, and their fill ports, maintain their settings during all vehicle operating conditions.

3.6.a.2 **METHOD**:

(1) Utilizing the Operations and Maintenance manual procedures, check to insure that nitrogen gas levels are properly set and maintaining their settings.

(2) For the first 2,000 miles, check

nitrogen levels to see if they were maintained after every 250 miles of operation.

(3) Thereafter, check nitrogen levels to see if they were maintained after every 500 miles of operation.

(4) Hydraulic fluid levels need not be checked unless seepage and/or leakage is noted.

(5) With all units properly set, methods and procedures should be determined for installation and charging of units without the use of blocks under the vehicle. This shall incorporate corrective values for different roadwheel stations and different weight conditions.

3.6.a.3 **RESULTS:** The HSS units did not meet the test plan requirements.

(1) The gas pressures in the suspension units had to be checked and adjusted on average every 50.4 miles or 5.9 hours of operation.

(2) The oil levels in the suspension units had to be topped-off on average every 79.1 miles or 9.3 hours of operation.

(3) Methods and procedures for installation and charging of units without the use of blocks under the vehicle have not been developed.

(4) See section 3.5.c.3 for test results concerning the fill ports.

3.6.b **RIDE HEIGHT:**

3.6.b.1 **PURPOSE:** To determine whether the HSS/AAV's height changes appreciably with time or temperature.

3.6.b.2 **METHOD:**

(1) Utilizing the Operations and Maintenance Manual Procedures, measure vehicle height at the four corners of vehicle hull at the following increments:

-Every 250 miles of operation
-Every two calendar months of operation
-At every ten degrees change in ambient temperature (when available and when testing at elevated/cold temperatures)

(2) Utilizing the weapon station sight or an inclinometer, measure vehicle attitude change (with time) after operational shutdown. This shall be performed to investigate effects on UGWS range card readings and system accuracy.

3.6.b.3 **RESULTS:** The data were not always consistent, but the ride height of the HSS units appears to be more affected by temperature changes when the ambient temperature changes when the ambient temperature is below 80°F. Also, as noted previously, the ride height changes more with temperature when the vehicle weight decreases.

(1) See Section 3.3.c(2) for the effects on ride height caused by "Dogging Down" the vehicle.

(2) At a vehicle weight of 53,500 pounds, after at least one hour of operating and with an ambient temperature increase of 10°F and the final temperature less than 80°F, the forward end of the HSS/AAV dropped an average 2.4 inches, or 14% of the height before heating. At the same time the aft end raised an average 2.6 inches, or 16.6% of the height before heating. Corresponding data at 58,100 pounds were not available.

(3) After cooling off 10°F from a maximum temperature less than 80°F for at least 12 hours, the bow of the 53,500 pound vehicle raised an average of 1.4 inches or 8.8% of the height before cooling. At the same time the stern dropped an average of 2.6 inches or 13.8% of the height before cooling. Corresponding data at 58,100 pounds were not available.

(4) For an ambient temperature increase of approximately 15°F with a starting temperature above 80°F, the bow height of the 53,500 pound vehicle either remained constant or rose less than 5%. The stern height remained constant. For the 58,100 pound vehicle, both the bow and stern heights remained constant.

(5) Upon cooling off for at least 12 hours to an ambient temperature greater than 80°F, the bow height of the 53,500 pound vehicle decreased slightly in one instance and increased very slightly in another. The stern height decreased an average of 1.5 inches or 9%. The one set of corresponding data for the 58,100 pound vehicle indicated no change in bow height and a slight decrease in stern height.

(6) Tests utilizing the UGWS sight or an inclinometer have not been conducted.

3.6.c <u>RETURN ROLLER WEAR:</u>

3.6.c.1 <u>PURPOSE:</u> To observe wear rate and deterioration of return (or support) rollers during testing.

3.6.c.2 <u>METHOD:</u> AVTB operations and maintenance personnel shall monitor and report on abnormal wear and replacement of return roller components. This shall include development and implementation of any test procedures to measure damage and determine replacement guidelines.

3.6.c.3 **RESULTS:** After sight glasses were installed in the return roller hubs to monitor lubricant levels, water contamination became a continuous problem. At 73 miles and 12 hours into the test the lubricant was changed from 30 Wt. to 15W-40. The following is compilation of test results concerning the return rollers:

(1) Port #1 roller was never replaced and accumulated 554 miles and 65 test hours.

(2) Port #2 roller was replaced at 17 miles and 2 hours into the test and then accumulated 534 miles and 63 test hours.

(3) Starboard #1 roller was replaced at 17 miles and 2 hours into the test and then accumulated 534 miles and 63 test hours.

(4) Starboard #2 roller was replaced at 17 miles and 2 hours into the test. It then accumulated 534 miles and 63 test hours before being replaced again.

3.6.d **ROADWHEEL/SUSPENSION UNIT INTERFERENCE:**

3.6.d.1 **PURPOSE:** To observe wear rate and deterioration that may result to roadwheel and/or suspension units as a result of interference between the components or as a result of terrain induced damage.

3.6.d.2 **METHOD:** AVTB operations and maintenance personnel shall monitor and report on abnormal wear and replacement of suspension units and roadwheels as a result of interference between the components or as a result of terrain induced damage. This shall include development and implementation of any test procedures to measure damage and determine replacement guidelines.

3.6.d.3 **RESULTS:** Much of the terrain chosen for hot weather testing was covered with loose, sharp, fist-sized rocks which were extremely damaging to track pads and the Bradley Roadwheel tires and wheel disks. After the completion of hot weather testing, the vehicle crew noted extreme abrasive wear had occurred between all the inner roadwheels and their corresponding HSS unit crankcase covers.

3.6.e **TRACK TENSION SETTING AND ADJUSTMENT:**

3.6.e.1 **PURPOSE:** To observe track tension, its effect on vehicle operation, and determine applicable setting and measurement guidance. This is required as a result of the support roller interface and the effect on track tension and proper setting.

3.6.e.2 **METHOD:** AVTB operations and maintenance personnel shall monitor and report on abnormal wear and replacement of track components as a result of interference between the track and suspension components or as a result of terrain induced damage. This shall include development and implementation of any procedures to determine and set proper track tension. AVTB shall experiment with and provide comments on ways to install and remove the track on the vehicle in various configurations and weights. This shall include estimates of crew levels, time required, numbers of personnel required and the need to remove EAAK panels (if necessary) for service to the track.

3.6.e.3 **RESULTS:**

(1) At 25 miles and 4 hours into the test, new track was installed on the HSS/AAV with 85 track blocks per side. In order to connect the track the #2 HSS unit must be de-pressurized on both sides because the vehicle rises about 4 inches when the track is disconnected.

(2) After this track accumulated 10 miles and 4 test hours, one track block had to be removed from each side to maintain proper tension with the adjusters.

(3) After a total of 304 miles and 36 test hours, another track block had to be removed from both sides for a current total of 83 blocks per side.

(4) A special tool was developed by Staff Sergeant Lowther to assist in installing track when EAAK is installed on the vehicle. Two used AAV track pins are welded end to end with one of the pins bent into two 90° angles with 7 inches between the bends. This provides an offset to pull the track over the return rollers without having to remove the EAAK panels on the sponsons.

(5) A minimum of 4 crewmen and 10 manhours were required to break and connect track.

3.6.f **INSTALLATION AND REMOVAL OF SUSPENSION UNITS:**

3.6.f.1 **PURPOSE:** To assess crew workload, level of difficulty, and anticipated maintenance burdens for this system that would be required for installation of units on the vehicle.

3.6.f.2 **METHOD:** AVTB operations and maintenance personnel (at various maintenance levels) shall perform suspension unit installation and removal in various configurations that could be anticipated by the FMF. This shall include, but not be limited to:

(1) Installation/removal while pressurized and unpressurized.

(2) Installation/removal with and

without hub attached.

(3) Installation/removal at stations 1, 3, 6 - port and starboard.

(4) Various lifting harnesses and lifting methods.

(5) Different vehicle weights
AVTB shall experiment with (in matrix format) and provide comments on possibilities for accomplishing the above efforts, and provide feedback on what changes should be considered for future vehicle configurations to facilitate easier installation and removal of units.

3.6.f.3 **RESULTS:** Two crewmen can perform removal/installation of HSS units.

(1) All of the 9 HSS units removed and replaced by AVTB personnel were unpressurized. Removal or installation while pressurized would be very dangerous and very difficult, if not impossible.

(2) All removals and installations of HSS units were accomplished without the Hub attached as any decrease in weight and bulk facilitates the procedures.

(3) Removal and installation procedures were performed at the port #1, #2, #3 and #5 stations, and at the starboard #1, #2, #4 and #6 stations.

(4) The lifting eye and boom of the HSS maintenance cart were used for all but one removal/installation procedures. On one occasion 2 crewmen performed an installation without using the cart crane just to see if this could be done. It was exceedingly difficult and not recommended except for emergency field repairs. The portable hydraulic ram supplied with the HSS maintenance cart was used to position the HSS unit for access to the bolt holes.

(5) HSS unit removal/installation procedures were accomplished with the vehicle empty, at 53,500 pounds and at 58,100 pounds.

3.6.g **SHORT TRACKING OF SUSPENSION UNITS:**

3.6.g.1 **PURPOSE:** To assess crew workload, level of difficulty, and anticipated maintenance burdens required for this system to be short tracked in a field environment.

3.6.g.2 **METHOD:** AVTB operations and maintenance personnel (at various maintenance levels) shall experiment with and perform short tracking of the vehicle in various configurations that could be anticipated by the FMF. This shall include, but not be limited to:

(1) Installation/removal of units to facilitate short tracking.

(2) Deactivation and tying up of units during short tracking.

(3) Impact of being towed when short tracked (using tow bars and cables)

(4) Removal of roadwheels and hubs.

(5) Different vehicle weights.

(6) Progressive increase and maximum number of roadwheel stations that can be deactivated (rear units, front units, mixed units).

AVTB shall experiment with (in matrix format) and provide comments on possibilities for accomplishing the above efforts, and provide feedback on what changes should be considered for future vehicle configurations to facilitate easier short tracking.

3.6.g.3 __RESULTS:__ AVTB has not conducted any short tracking experiments with the HSS/AAV. It should be noted that the HSS units cannot be swapped from one side of the vehicle to the other.

3.7 __RELIABILITY, AVAILABILITY, MAINTAINABILITY AND DURABILITY:__ New vehicle hardware must not provide a logistics and maintenance burden for the sake of improved performance. Reliability and maintainability must be documented and validated to evaluate the new system benefits.

3.7.a __PURPOSE:__ To determine the test item's anticipated RAM-D characteristics during the test period.

3.7.b __METHOD:__

(1) Operate the test vehicle as outlined in paragraph 2.1 of the test plan. Maintain the vehicle and suspension system as outlined in the appropriate technical manuals.

(2) Perform all crew level maintenance actions required during the test operations and report in accordance with standard procedures.

3.7.c __RESULTS:__ In summary there were 9 HSS unit failures requiring replacement over 554 test miles and 65 test hours. This yields an average of 61.6 miles and 7.2 hours between HSS unit failures. In addition there were 4 return roller failures for an average of 138.5 miles and 16.3 hours between failures.

(1) The following is a compilation of maintenance actions concerning HSS/AAV suspension components over the period from 27 April 1990 to 15 November 1990:

Weight	Date	Position/ Serial No.	Pressure Before	Pressure After	Oil Added	Ambient Temp.	Miles Since Last Check	Total Miles on Unit	Hours Since Last Check	Total Hours on Unit	Remarks
	3 May	#1 Port/#7					8		1		Oil Leak Behind Spindle
	9 May	#1 Port/#5	0/0	3200/70			0	At Least 8	0	At Least 1	Replaced Ser. #7 arm with Ser. #5
	9 May	#2 Stbd/#13	70 Low Side	120 Low Side							Internal pressure leak from high side to low side
		#3 Stbd/#10	70 Low Side	120 Low Side							
		#2 Port/#2	70 Low Side	110 Low Side							
	10 May	#1, #2 Stbd, #2 Port Support Rollers						At Least 17		At Least 2	Replaced Rollers
	11 May	#4 Stbd/ #16	0/0	1600/70			9	At Least 17	1	At Least 2	Replaced Ser. #11 w/Ser. #16 Due to Oil Leak
		#5 Stbd Inner, #6 Stbd outer Roadwheels									Replaced Roadwheels
		Port and Stbd Track									Replaced Track w/used Track from P4
	15 May	#1 Port/#5	3000	3200/70			17	17	2	2	Pressures in all units adjusted
		#2 Port/#2	3000	3200/70							
		#3 Port/#3	1500	1600/70							
		#4 Port/#4	1560	1600/70							
		#5 Port/#6	1560	1600/70							
		#6 Port/#1	1550	1600/70							
		#1 STBD/#8 #2 STBD/#13 #3 STBD/#10	3000 3000 1500	3200/70 3200/70 1600/70							
		#4 STBD/#16	1570	1600/70			8	8	1	1	
		#5 STBD/#14 #6 STBD/#9	1540 1460	1600/70 1600/70							

Weight	Date	Position/ Serial No.	Pressure Before	Pressure After	Oil Added	Ambient Temp.	Miles Since Last Check	Total Miles on Unit	Hours Since Last Check	Total Hours on Unit	Remarks
49,000	16 May	Forward Port 18 1/4" Forward STBD 17 1/2" AFT Port 19 3/4" AFT STBD 19 1/2"									Check ground clearance at different weights and load configurations
55,000		FP 18 1/4 FS 17 1/2 AP 16 1/4 AS 13 3/4									Weight Centered
55,000		FP 17 1/4 FS 16 1/2 AP 15 3/4 AS 15 1/4									Weight Forward
59,000		FP 20 5/8 FS 21 AP 9 AS 9 1/2 Track Tension Adjusters 6 3/4 P & S									Weight Centered
59,248	23 May	FP 20 1/2 FS 20 1/4 AP 10 1/4 AS 10 1/4					0		1		Checked Ground Clearance
53,148	6 Jun	Track									Replaced Track
	5 Jul	EAAK									Finished EAAK Installation
	6 Jul	#1 STBD Support Roller									Installed Sight Glass to Monitor Lubricant
47,500	10 Jul	FP 15 FS 15 1/4 AP 14 5/8 AS 14 1/16					0		0		Checked Ground Clearance

Weight	Date	Position/ Serial No.	Pressure Before	Pressure After	Oil Added	Ambient Temp.	Miles Since Last Check	Total Miles on Unit	Hours Since Last Check	Total Hours on Unit	Remarks
	13 Jul	#1 Port/#5		3200/70			10	27	5	7	Checked all Pressures
		#2 Port/#2		3200/70			10		5		
		#3 Port/#3		1975/70			10		5		
		#4 Port/#4		1975/70			10		5		
		#5 Port/#6		1975/70			10		5		
		#6 Port/#1		1975/70			10		5		
		#1 STBD/#8		3200/70			10		5		
		#2 STBD/#13		3200/70			10		5		
		#3 STBD/#10		1975/70			10		5		
		#4 STBD/#16		1975/70			10	18	5	6	
		#5 STBD/#14		1975/70			10		5		
		#6 STBD/#9		1975/70			10		5		
	17 Jul	Track Block									1 Block Removed From Each Side Side (Now 84 Blocks)
	19 Jul	#1 Port/#5	3010/110	3200/70			48	65	9	11	Suspension Units Leak Pressure. Adjust Pressures.
		#2 Port/#2	335/82	3200/70			48		9		
		#1 STBD/#8	1515/0	3200/70							
		#2 STBD/#13	2815/120	3200/70			48		9		
58,100	23 Jul	Support Rollers						73		12	58,100 Pounds Finalized as Upper Weight Limit. Changed oil from 30 WT to 15W/40. Machined Hubs to Accomodate 9/16 Head on Plugs.

Weight	Date	Position/ Serial No.	Pressure Before	Pressure After	Oil Added	Ambient Temp.	Miles Since Last Check	Total Miles on Unit	Hours Since Last Check	Total Hours on Unit	Remarks
	25 Jul	#2 Port/#7					48	At least 73	8	At least 12	Replaced HSS units; Would not hold Pressure. #7 For #2, #11 For #8.
		#1 STBD/#11					48	At least 73	8	At least 12	
	6 Aug	FP 13 1/4 FS 13 AP 17 AS 17					67		12		Checked Ground Clearance Undogged.
		FP 10 1/2 FS 10 AP 17 AS 17					0		0		Checked Ground Clearance After Dogging Down.
	7 Aug	FP 13 FS 12 AP 17 AS 16 4					6		(13 Hours Dogged Down)		Checked Ground Clearance After Undogging After 13 Hours.
		FP 13 1/4 FS 13 AP 17 AS 17					(20 Feet)		0		Checked Ground Clearance After Moving 20 Feet.
53,500	8 Aug	#5 Port Roadwheel									Replaced Hub O-Ring.
		#2 Port Support Roller					56	116	8	19	Replaced Hub O-Ring.
		STBD Idler Bearing						At Least 129		At Least 20	Replaced STBD Idler Bearing.
		FP 17 FS 21 AP 17 AS 21 1/2					29		3		Checked Ground Clearance After Breaking STBD. Track
		FP 17 FS 19 AP 17 AS 19					0		0		Checked Ground Clearance After Buttoning-up STBD. Track

Weight	Date	Position/ Serial No.	Pressure Before	Pressure After	Oil Added	Ambient Temp.	Miles Since Last Check	Total Miles on Unit	Hours Since Last Check	Total Hours on Unit	Remarks
		#1 STBD/#11	2875	3235			56	56	8	8	Had to Depressurize #2 STBD to Button-up Track.
		#2 STBD/#13		3500			94		12		
		#2 Port/#7	2600	3200			56	56	8	8	
	9 Aug	#1 Port					56		8	19	Replaced Support Roller Hub O-Rings.
		#1 STBD					56	116	8	19	
		#2 Support Rollers					56	116	8	19	
											53,500 is Now The Lower Weight Limit.
58,100	21 Aug	#3 Port/#3 #4 Port/#4 #6 Port/#1 #2 STBD/#13									These Units are Leaking Fluid.
		FP 17 FS 16 1/2 AP 14 3/4 AS 14 3/4				≈80°F	45		6		Checked Ground Clearance.
		FP 17 FS 16 1/2 AP 14 3/4 AS 14 3/4				≈100°F	11		1.3		
	22 Aug	#2 STBD/#8		3560			35	At Least 201	5	At Least 30	Replaced Unit Ser. #13 With #8.
		FP 17 FS 16 1/2 AP 14 AS 14				≈80°F	0		0		Checked Ground Clearance
		FP 17 FS 16 1/2 AP 14 AS 14				100°F	13.5		1.7		
	23 Aug	#2 STBD/#8	2925	3380			13	13	2	2	Checked Pressure

Weight	Date	Position/ Serial No.	Pressure Before	Pressure After	Oil Added	Ambient Temp.	Miles Since Last Check	Total Miles on Unit	Hours Since Last Check	Total Hours on Unit	Remarks
53,500	24 Aug	FP 18 1/2 FS 18 AP 17 AS 17				≈80°F	52		6		Checked Ground Clearance
		FP 18 1/2 FS 18 AP 17 AS 17				98°F	15		1.5		
	25 Aug	#6 STBD/#9			1 oz.						Added Oil
		#1 Port Sup-port Roller					122		.15		Added Oil to all Support Rollers
		#2					122	238	15	34	
		#1 STBD					122	238	15	34	
		#2					122	238	15	34	
	26 Aug	FP 17 FS 16 3/4 AP 14 1/2 AS 14 1/2				83°F					Checked Ground Clearance
		FP 17 1/2 FS 17 1/2 AP 14 1/2 AS 14 1/2				98°F					
	27 Aug	FP 17 1/2 FS 18 AP 14 AS 14				88°F	0		0		Checked Ground Clearance
		FP 17 1/2 FS 19 1/2 AP 16 1/2 AS 17									
		STBD #5/#14				98°F					Leaking Oil From Spindle Seals
		#6/#9				98°F					

Weight	Date	Position/ Serial No.	Pressure Before	Pressure After	Oil Added	Ambient Temp.	Miles Since Last Check	Total Miles on Unit	Hours Since Last Check	Total Hours on Unit	Remarks
	27 Aug	STBD #2 Inner and Outer Roadwheels									Both Roadwheels Bad
	2 Sep	Port #3/#3			1 oz	95°F					Added Oil
		STBD #6/#9			1 oz	95°F	67		6		
	3 Sep	STBD #1/#11	3045	3245			202	258	23	30	Adjusted Pressures
		#2/#8	2685	3245			94	107	.9	11	
		#3/#10	1665	1975			296		35		
		#4/#16	695	1975			296	316	35	41	
		#5/#14	1310	1975			296		35		
		#6/#9	1420	1975			296		35		
		Port #3/#3			1 oz		13		2		Added Oil
		STBD #6/#9			1 oz		13		2		
		STBD #1 and #2 Port #2									Dowel Pins Backing out of Hull Flange
	4 Sep	Port #1/#5	2140	3245		92°F	299	325	35	42	Adjusted Pressures
		#2/#7	2710	3245		92°F	202	258	23	31	
		#3/#3	1845	1975		92°F	299		35		
		#4/#4	1740	1975		92°F	299		35		
		#5/#6	1825	1975		92°F	299		35		
		#6/#1	1700	1975		92°F	299		35		
	5 Sep	FP 161/2 FS 16 AP 18 AS 18				89°F					Checked Ground Clearance

Weight	Date	Position/ Serial No.	Pressure Before	Pressure After	Oil Added	Ambient Temp.	Miles Since Last Check	Total Miles on Unit	Hours Since Last Check	Total Hours on Unit	Remarks
53,500	12 Sep	FP 14 FS 13 3/4 AP 19 3/4 AS 19 1/2				78°F					Checked Ground Clearance
		Track Blocks						304		36	Removed 1 Block From Each Side (83)
		STBD #1/#11	3130			78°F	6	264	1	32	Checked Pressures
		#2/#8	2540			78°F	6	113	1	12	
		#3/#10	1860			78°F	6		1		
		#4/#16	1465			78°F	6	322	1	42	
		#5/#14	1915			78°F	6		1		
		#6/#9	1775			78°F	6		1		
	13 Sep	Port #1/#5	2780			78°F	6	331	1	43	Checked Pressures
		#2/#7	2915			78°F	6	264	1	32	
		#3/#3	1785			78°F	6		1		
		#4/#4	1735			78°F	6		1		
		#5/#6	1760			78°F	6		1		
		#6/#1	1775			78°F	6		1		
		STBD #2/#13						113		12	Replaced due to Loss of Pressure, #13 for #8
	17 Sep	Port #1/#2						331		43	Replaced Due to Loss of Pressure, #2 for #5
		Port #1/#2	0	3200		75°F	0	0	0	0	Adjusted Pressures
		#2/#7	3215	3515		75°F	0	264	0	32	
		#3/#3	1785	1995		75°F	0		0		
		#4;#4	1740	1995		75°F	0		0		

Weight	Date	Position/ Serial No.	Pressure Before	Pressure After	Oil Added	Ambient Temp.	Miles Since Last Check	Total Miles on Unit	Hours Since Last Check	Total Hours on Unit	Remarks
		STBD #2/#13						113		12	Replaced Due to Loss of Pressure, #13 for #8
	17 Sep	Port #1/#2						331		43	Replaced Due to Loss of Pressure, #2 for #5
		Port #1/#2	0	3200		75°F	0	0	0	0	Adjusted Pressures
		#2/#7	3215	3515		75°F	0	264	0	32	
		#3/#3	1785	1995		75°F	0		0		
		#4/#4	1740	1995		75°F			0		
		#5/#6	1760	1990		75°F	0		0		
		#6/#1	1760	1990		75°F	0		0		
		All Inside Roadwheels									Rubbing on Bottom Half of HSS Crankcase Cover
	18 Sep	Port #3/#3			1 oz		6		1		Added Oil
		#5/#6			1 oz						
		STBD #3/#10			1 oz						
		#6/#9			1 oz		6		1		
	19 Sep	FP 14 FS 14 AP 23 AS 23				77°F					Checked Ground Clearance
	20 Sep	STBD #2/#13		Bled Low Side to 0		68°F	20	20	2	2	Leak From High Side to Low Side
			0	Low Side 100		77°F	29	49	3	5	
		FP 15 1/2 FS 15 3/4 AP 19 1/2 AS 19 1/4				68°F	20		2		Checked Ground Clearance

Weight	Date	Position/ Serial No.	Pressure Before	Pressure After	Oil Added	Ambient Temp.	Miles Since Last Check	Total Miles on Unit	Hours Since Last Check	Total Hours on Unit	Remarks
		Port #1/#2	3130	3205		68°F	20	20	2	2	Adjusted Pressures
		#2/#7	3300	3205			20	284	2	34	
		STBD #1/#11	3260	3215			20	284	2	34	
		#2/#13	2635	3210			20	20	2	2	
		FP 16 1/2 FS 15 3/4 AP 19 1/2 AS 19 1/4				77°F	29		3		Checked Ground Clearance
	24 Sep	FP 17 FS 17 AP 16 AS 16				68°F	0		0		Checked Ground Clearance
		Port #3/#3			1 oz	78°F	62		8		Added Oil
		STBD #2/#13			1 oz	78°F	14	62	3	8	
		#6/#9			1 oz	78°F	62		8		
		FP 16 FS 15 1/4 AP 18 AS 17				78°F	14		3		
		Port #2 Support Roller									Changed Contaminated Oil
	25 Sep	FP 18 FS 17 AP 16 AS 15 1/2				65°F	0		0		Checked Ground Clearance
		FP 14 1/2 FS 13 1/2 AP 19 1/2 AS 19 1/2				75°F	27		2		

Weight	Date	Position/ Serial No.	Pressure Before	Pressure After	Oil Added	Ambient Temp.	Miles Since Last Check	Total Miles on Unit	Hours Since Last Check	Total Hours on Unit	Remarks
	26 Sep	Port and STBD #2 Support Rollers				75°F	27		2		Changed Contaminated Oil
58,100	28 Sep	Port #1/#2	3005	3205			69	89	8	10	Adjusted Pressures
		#2/#7	2820	3220			69	353	8	42	
		#3/#3	1820	1990			89		10		
		#4/#4	1860	1985			89		10		
		#5/#6	1850	1980			89		10		
		#6/#1	1820	1980			89		10		
		STBD #1/#11	3205	OK			69	353	8	42	
		#2/#13	2480	3220			69	89	8	10	
		#3/#10	1775	1985			89		10		
		#4/#16	1280	1980			89	411	10	52	
		#5/#14	1830	1990			89		10		
		#6/#9	1720	1990			89		10		
		FP 17 FS 16 3/16 AP 14 3/4 AS 14 3/4				75°F	1		1		
53,500	3 Oct	Port and STBD #2 Support Rollers					17		3		Changed Contaminated Oil
	10 Oct	Port #2/#7			1 oz		26	379	4	46	Added Oil
		STBD #3/#10			1 oz		26		4		
		#6/#9			1 oz		26		4		

Weight	Date	Position/ Serial No.	Pressure Before	Pressure After	Oil Added	Ambient Temp.	Miles Since Last Check	Total Miles on Unit	Hours Since Last Check	Total Hours on Unit	Remarks
	10 Oct	FP 15 1/2 FS 15 1/4 AP 18 1/2 AS 18 1/2				65°F	26		3		Checked Ground Clearance
		FP 15 3/4 FS 15 1/2 AP 17 1/2 AS 17				75°F	8				
	18 Oct	Port #1/#2	3070/70	3215/70			34	123	5	15	Adjusted Pressures
		#2/#7	2205/70	3220/70			34	387	5	47	
		#3/#3	1900/0	1985/0	1 oz		34		5		
		#4/#4	1820/0	1980/70			34		5		
		#5/#6	1790/0	1990/70			34		5		
		#6/#1	1800/0	1985/70	1 oz		34		5		
		STBD #1/#11	3005/0	3220/70			34	387	5	47	
		#2/#13	2700/0	3215/0	1 oz		34	123	.5	15	
		#3/#10	1760/0	1980/70			34		5		
		#4/#16	1345/50	1980/70			34	444	5	57	
		#5/#14	1785/0	1980/70			34		5		
		#6/#9	1570/0	1990/0			34		5		
	19 Oct	Port #2/#7					16	403	1	48	All Hull Flange Bolts Loose
											Locked in Retracted Position Temporarily
	23 Oct	STBD #2 Support Roller					109	534	8	63	Replaced Roller
	25 Oct	Port #2/#7									Repaired Low Pressure Cap Threads

Weight	Date	Position/ Serial No.	Pressure Before	Pressure After	Oil Added	Ambient Temp.	Miles Since Last Check	Total Miles on Unit	Hours Since Last Check	Total Hours on Unit	Remarks
	26 Oct	Port #1 and					109	554	8	65	Changed Contaminated Hub Oil
		#2 Support Rollers					109	534	8	63	
	6 Nov	Port #3/#5					92	At least 554	6	At least 65	Replaced Units; #5 for #3, #8 for #9
		STBD #6/#8					92	At least 554	6	At least 65	
	9 Nov	Port #3 Roadwheels									Installed New Inner and Outer Roadwheels
	15 Nov	#1 Port/#2	3095	3220			92	215	6	21	Adjusted Pressures
		#2 /#7	3220	3220			92	479	6	53	
		#3 /#5	0	1975			0	0	0	0	
		#4 /#4	1500	1985			92	At Least 554	6	At Least 65	
		#5 /#6	1810	1985			92	At Least 554	6	At Least 65	
		#6 /#1	1645	1980			92	At Least 554	6	At Least 65	
		#1 STBD/#11	2695	3220			92	479	6	53	
		#2 /#13	2880	3220			92	215	6	21	
		#3 /#10	1980	1980			92	At Least 554	6	At Least 65	
		#4 /#12	1220	1980			92	536	6	63	
		#5 /#14	1920	1980			92	At Least 554	6	At Least 65	
		#6 /#8	0	1985			0	0	0	0	

(2) The proposed Operation and Maintenance Manual for HSS Installed on P-7 Amphibious Assault Vehicle dated 5 October 1989 was evaluated by the HSS/AAV crew which performed most of the inspection/repair of the vehicle's suspension. The following are the crew chief's comments concerning section 6.2, Removing/Replacing Suspension Unit:

The instructions for removal and replacement of support rollers and HSS arms that are listed in the proposed maintenance procedure are similar to the procedure being used by the crew of PX 12-10. Exceptions or additions include: During removal of any HSS arm with the vehicle on blocks (17") placed under each corner of the vehicle, it is necessary to raise the arm with the porta power placed against the forward side of the arm and lift the arm high enough to reposition the porta power underneath the arm. In order to remove the bolt (which is at 3 o'clock) blocks were placed underneath the porta power to lift the arm high enough to allow the crewman access to the (3 o'clock) bolt. Removal of the bolt at the 5 o'clock position requires the arm to be pushed to the furthest most downward position. This can be done by using a tank bar or the easier method of positioning the porta power on the top side of the arm and blocks on top of the track to brace the track against the longitudinal drive shaft cover brackets. By pumping the porta power the arm will be pushed down far enough for the crewman to have access to the bolt at the 5 o'clock position.

(3) The photographs in the proposed manual were useless because of contrast lost when they were copied.

(4) On at least 4 of the HSS units it was noted that the hull flange dowel pin had started to back out of the flange.

(5) The maintenance cart was used for all but one of the nine HSS unit removal/installation iterations and for all fluid level and gas pressure adjustments. An air compressor integral to the cart itself would improve its utility. The Portable Hydraulic Ram with its HSS roadarm lifter was used on all HSS removal/installation procedures, but not necessarily in the manner described in the proposed manual.

3.8 <u>TOWING TESTS:</u> All changes and improvements to the AAV family must be done without sacrificing or degrading current vehicle performance and capabilities.

3.8.a <u>PURPOSE:</u> Comparative testing of the operation and handling qualities of this modified vehicle versus a standard AAV shall be performed when towing various items. Measurements required will be qualitative and quantitative.

3.8.b <u>METHOD:</u> A test matrix shall be established and the following towing tests shall be performed with the vehicle in weight conditions A and B. Video coverage shall document vehicle operations.

(1) Towing shall be conducted over the following terrains:

- -Loose Sand
- -Packed Sand
- -Secondary Roads
- -Paved Roads
- -Cross Country Terrain
- -Mud/Clay
- -Vegetated

(2) Towing shall be conducted (using tow bars and cables) with the following items towed by the HSS/AAV:

- -AAV of Equal or Less Weight
- -M198 155mm Towed Artillery
- -Standard Trailer
- -Trailer Mounted Line Charge
- -Other Equipment Deemed Appropriate by AVTB

(3) A baseline AAV at equivalent weight shall tow the HSS/AAV.

3.8.c **RESULTS:** The towing tests conducted thus far have not indicated any problems with the HSS/AAV as either a towing or a towed vehicle. The following is a matrix compilation of the towing test results. An "X" indicates successful completion of that particular test. A "TNA" indicates that the terrain was not available due to logistical or environmental considerations. A "VNA" indicates that the vehicle/equipment to be towed was not available. For towed vehicles:

A= Standard AAV
H= HSS/AAV
M= M198 155mm Towed Artillery
T= Standard Trailer
L= Trailer Mounted Line Charge
O= Other Equipment (Specified)

Towing Vehicle	HSS/AAV at 53,5 0 Pounds					HSS/AAV at 58 100 Pounds					Standard AAV at 53,500 Pounds					Standard AAV at 58,100 Pounds				
Towed Vehicle/ Equipment	A	M	T	L	O	A	M	T	L	O	H	M	T	L	O	H	M	T	L	O
Terrain and Whether Tow Bar (TB) or Tow Cable (TC) Was Used																				
Loose Sand W/TB	X	VNA	VNA	VNA		X	VNA	VNA	VNA		X	VNA	VNA	VNA		X	VNA	VNA	VNA	
Loose Sand W/TC	X	VNA	VNA	VNA		X	VNA	VNA	VNA		X	VNA	VNA	VNA		X	VNA	VNA	VNA	
Packed Sand W/TB	X	VNA	VNA	VNA		X	VNA	VNA	VNA		X	VNA	VNA	VNA		X	VNA	VNA	VNA	
Packed Sand W/TC	X	VNA	VNA	VNA		X	VNA	VNA	VNA		X	VNA	VNA	VNA		X	VNA	VNA	VNA	
Secondary W/TB		VNA	VNA	VNA			VNA	VNA	VNA			VNA	VNA	VNA			VNA	VNA	VNA	
Secondary W/TC	X	VNA	VNA	VNA		X	VNA	VNA	VNA		X	VNA	VNA	VNA		X	VNA	VNA	VNA	
Paved W/TB	X	VNA	VNA	VNA		X	VNA	VNA	VNA		X	VNA	VNA	VNA		X	VNA	VNA	VNA	
Paved W/TC	X	VNA	VNA	VNA		X	VNA	VNA	VNA		X	VNA	VNA	VNA		X	VNA	VNA	VNA	
Cross Country W/TB	X	VNA	VNA	VNA		X	VNA	VNA	VNA		X	VNA	VNA	VNA		X	VNA	VNA	VNA	
Cross Country W/TC	X	VNA	VNA	VNA		X	VNA	VNA	VNA		X	VNA	VNA	VNA		X	VNA	VNA	VNA	
Mud/Clay W/TB	TNA	TNA	TNA	TNA	TNA	TNA	TNA	TNA	TNA	TNA	TNA	TNA	TNA	TNA	TNA	TNA	TNA	TNA	TNA	TNA
Mud/Clay W/TC	TNA	TNA	TNA	TNA	TNA	TNA	TNA	TNA	TNA	TNA	TNA	TNA	TNA	TNA	TNA	TNA	TNA	TNA	TNA	TNA
Vegetated W/TB	TNA	TNA	TNA	TNA	TNA	TNA	TNA	TNA	TNA	TNA	TNA	TNA	TNA	TNA	TNA	TNA	TNA	TNA	TNA	TNA
Vegetated W/TC	TNA	TNA	TNA	TNA	TNA	TNA	TNA	TNA	TNA	TNA	TNA	TNA	TNA	TNA	TNA	TNA	TNA	TNA	TNA	TNA

3.9 EFFECT OF POWER PACK CONDITION ON VEHICLE SPEED:

3.9.a **PURPOSE:** To determine if the condition of the engine/transmission installed in the HSS/AAV was the reason for the vehicle's top speed being less than the standard AAV.

3.9.b **METHOD:** The HSS/AAV and the standard AAV will be timed through a measured 3 miles over packed sand at weight conditions A and B. Both vehicles will enter the measured mile at full speed and be driven by the same driver. Then the engine/transmission from the standard AAV will be installed in the HSS/AAV. The HSS/AAV will then be timed again through the measured 3 miles to see if any change in top speed is effected.

3.9.c **RESULTS:** As can be seen from the following matrix, switching power packs from the faster standard AAV to the slower HSS/AAV actually further decreased the HSS/AAV's speed by 9.6%. Other factors in the HSS suspension, such as the inner roadwheels rubbing on the HSS crankcase cover, must be the reason for the decreased performance.

Power Pack	HSS/AAV		Standard AAV	
	53,500 LB	58,100 LB	53,500 LB	58,100 LB
	20.0 MPH	18.75 MPH	23.08 MPH	25.0 MPH
Switched	18.09 MPH			

The results of the first speed run after changing the power pack in the HSS/AAV indicated that further testing was unnecessary.

Contract N00167-88-C-0024, CDRL Item A013, Drawings, Engineering and Associated Lists, Engineering Drawings (Level III)

Naval Sea Systems Cmd Part Number	CGT Part Number	Description
6599761	700340	6K ISU Envelope Dwg.
6599762	700341	6K Unit Assembly Dwg.
6599763	700001F	Forging, Roadarm
6599764	700001	Machining, Roadarm
6599765	700015	Spindle, Wheel, Vehicle
6599766	41181	Screw, Valve, ISU
6599767	41182	Stem, Valve, ISU
6599768	700338	Cover, Charge Valve
6599769	700097	Drain Plug, Oil Chamber
6599770	700327	T-Ring Seal, Male Piston
6599771-TAB	700328-TAB	Hollow Hex Plug, Straight Thread
6599772	700004	Endcap, Roadarm
6599773	700005	Endcap, Accumulator
6599774	700037	Sleeve, Actuator Cyl
6599775	700034	Spacer, Actuator Cyl
6599776	700011	Ass'y Piston/Liner
6599777	700009	Piston, Actuator
6599778	700013	Glyd Ring
6599779	700012	Seal, Actuator
6599781	700069	Spring, Compression Seal
6599782	700033	Spacer, Seal
6599783	700035	Ring, Spacer
6599784	700036	Cap, Actuator Piston
6599785	700038	Ring, Connecting Bar Retainer
6599786	700329	Retaining Ring, Internal Medium Duty
6599787	700043	Conn. Bar Assy
6599788	700044	Rod, Connecting Bar
6599789	700045	Ball, Conn Bar
6599790	700021	Pin, Connecting Bar
6599791	700335	Cam, Actuator Pump
6599792	700326	Bolt, Cam
6599793	700000-C	Spindle, Casting
6599794	700000	Spindle, Roadarm Machining
6599795	700314	Pin, Torque To Unit Hull
6599796	700042	Bearing, Conn Bar
6599797	700313	Pump Assembly, Damper
6599798	700027	Piston, Pump
6599799	700041	Spring, Pump
6599800	700312	Race, Outer
6599801	700311	Race, Inner
6599802	700047	Bearing, Needle
6599803	700025	Check Valve Seat
6599804	700026	Spring Buide, Check Valve
6599805	700039	Spring, Valve, Check

Contract N00167-88-C-0024, CDRL Item A013, Drawings, Engineering and Associated Lists, Engineering Drawings (Level III) (Continued)

Naval Sea Systems Cmd Part Number	CGT Part Number	Description
6599806	700032	Sleeve/Spool Matching Relief Valve
6599807	700031	Sleeve, Relief Valve
6599808	700029	Spool, Relief Valve
6599809	700030	Spring, Guide, Relief Valve
6599810-TAB	700024	Shim, Relief Valve
6599811	700040	Spring, Valve Relief
6599812	41198-2	Seal, Oil Crankcase
6599813	41199	Seal, Crankcase, Dust
6599814	700046	Main Bearing Ass'y
6599815	700014	Retainer, Bearing
6599816	700048	Shim, Bearing Retainer
6599817	39895	Screw, Brg Retainer
6599818	700019	Piston, Damper
6599819	700316	Spring, Damper
6599820	700017	Disc, Stator Assy ISU
6599821	700018	Disc, Rotor
6599822	700320	Spindle/Stator Ass'y
6599823	700023	Stator, Damper ISU
6599824	700022	Retainer, Damper
6599825	700304	Cover, Accumulator
6599826	38514-F	Cover, Forging
6599827	700002	Cover, Torque
6599828	700315	Pin, Drive
6599829	700321	Stop Block, Rebound, Spindle
6599830	700322	Stop Block, Rebound, Roadarm
6599831	700324	Spacer, Hub
6599832	700330	Adapter, Fill
6599833	42503	Valve, Fill
6599834	700332	Adapter, Relief Valve
6599835	700334	Valve, Relief
6599836	700306	Hull Mod. Machining
6599837	700339	Skid Plate Ass'y
6599838	700305	Hull Mounting Bracket
6599839	700303	Base, Support Roller W/C
6599840	700050	Spindle, Support Roller
6599841	700310	Wheel, Support Roller Mod.
6599842	700104	Cap, Hub
6599843	700016	Support Roller Ass'y
6599844	700342	Installation, 6K ISU on AAV-7
6599845	700008	Hull Modification
6599846	700343	6K ISU/Wheel Spindle Assembly
6599847	700007	Plug
6599848	700331	Plug
6599849	700344	Washer, Locking Tab

Contract N00167-88-C-0024, CDRL Item A013, Drawings, Engineering and Associated Lists, Engineering Drawings (Level III) (Continued)

Naval Sea Systems Cmd Part Number	CGT Part Number	Description
6599852	P39873	Valve, Relief
6599853	10866118	Nut, Slotted, Hex
6599854	LO 102488-2	Relief Valve Fixture
6599855	LO 102488-1	Check Valve Fixture

Cadillac Gage TEXTRON

AMS/721/RIDEMETR

3 O~tober 1989

OPERATION AND CALIBRATION MANUAL

ABSORBED POWER METER

MODEL NO. LO 022489-1

DESCRIPTION

The absorbed power meter consists of a main processor unit, a remote meter panel with pendant start-stop switch, and associated cables. The main processor is housed in the smaller half of a hinged aluminum carrying case while the remote panel and cables are stored in the cover of the case. When used in conjunction with a suitable accelerometer the unit provides the capability of reading:

(1) The time duration (up to 120 seconds) between a start and stop signal of a run.

(2) The unweighted peak instantaneous acceleration in gravity units during that run (up to 12 G's).

(3) The accumulated absorbed energy (up to 1200 watt-seconds in the X10 position) during that run.

The average absorbed power in watts is calculated by dividing the accumulated energy in watt-seconds by the run duration in seconds.

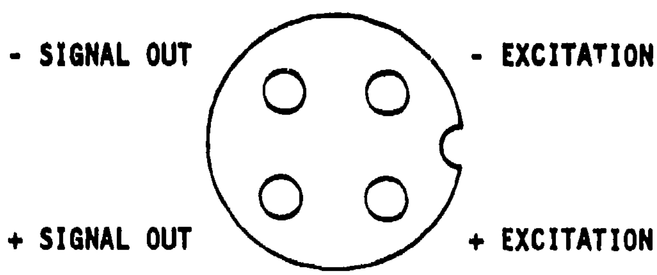
In addition, the instrument provides analog voltage input and outputs for external recording devices. The analog output signals available are the instantaneous acceleration in gravity units or foot per second-squared units, and the instantaneous absorbed power in watts. A properly scaled analog recording of instantaneous acceleration can be fed into the instrument to determine the average absorbed power during any selected time segment of the recording.

ELECTRICAL INTERCONNECTIONS

1. The 5-pin receptacle provided with the instrument as input to the accelerometer channel (marked ACCEL) should be wired as follows:

PIN A	-	+ EXCITATION (+5.0 V.D.C.)
PIN B	-	- EXCITATION (POWER GROUND)
PIN C	-	+ SIGNAL OUT
PIN D	-	- SIGNAL OUT (SIGNAL GROUND)
PIN E	-	NO CONNECTION

If the suggested Sensotec JTF accelerometer is used, its mating connector will be wired like this:



Suitable adjustments can be made for other accelerometers.

2. The instrument power cable (to be connected to panel receptacle marked POWER) is terminated with a 3-pin connector wired as follows:

PIN A	-	RED WIRE
PIN B	-	NO CONNECTION
PIN C	-	BLACK WIRE

The red wire must be connected to the positive terminal of the nominal 24 volt direct current source. The black wire is to be connected to the negative voltage terminal which is assumed to correspond to vehicle ground.

CAUTION: This unit should not be used on a vehicle with the positive battery terminal connected to ground, unless special provisions are made to insulate all elements of the instrument from vehicle ground.

3. Connect the remote interconnect cable between the main processor (receptacle marked REMOTE) and the appropriate receptacle at the remote meter panel.

4. Connect the receptacle associated with the start-stop pendant switch to the other remote meter panel receptacle.

OPERATION

The instrument requires nominal military vehicle power of 18-30 volts DC at approximately 200 milliamperes. The unit is current protected with a 1/2 ampere fast blow SB fuse and voltage protected against application of reverse polarity.

Power is applied to the unit when the power leads are connected and is verified by noting the presence of digits and yellow backlighting on the remote meter.

It is necessary to place a jumper between the RED banana jacks labelled ACC OUT and TAPE IN on the main panel for proper meter operation, unless acceleration data is fed in from an external analog recorder.

The remote panel meter switch should be placed in the TIME position. This is done to assure that the timer is stopped. If it is running, the operator should quickly depress and release the START-STOP button to stop the timer. Then the operator should set the main unit range switch in the X1 position for smooth to moderate terrain, or in the X10 position for rough terrain. Changing the range switch during or after the measurement run invalidates the run data because it controls the rate of the energy averaging process and not the meter scale factor. The range switch affects only the scale factor of the energy and power units, WATT-SEC and ABRB PWR OUT, and not the TIME or PEAK ACCEL readings. In the X1 position the unit reads directly in watt-seconds. In the X10 position the scale reading must be multiplied by 10 to obtain the correct total energy reading. For example, a meter reading of 098.3 watt-seconds with the range switch in the X10 position should be interpreted as a value of 983.0 watt-seconds.

Just prior to the start of the run, the RESET button on the remote panel meter should be depressed and held for about one second to insure complete reset of all the functions. Subsequently, on any of the functions, a stationary reading of ± 0.1 at the start is considered acceptable.

The operator determines the start of the run by quickly depressing and releasing the hand held START-STOP button. This starts the timer, the peak acceleration acquisition, and the energy accumulation process. The three position meter switch can select PEAK ACCEL or TIME or WATT-SEC. If the meter is in the TIME position during the run, the operator can choose to stop the run based on the timer reading. The run is terminated when the operator quickly depresses and releases the START-STOP button again. It is recommended that the three readings be taken and recorded together with the range switch position within one minute after the completion of the run. Since the readings are held in analog form, a small amount of drift is inevitable.

In the TIME position, the meter reads in seconds and tenths of seconds up to a maximum of 120.0 seconds. In the PEAK ACCEL position the meter reads in G's and tenths of G's up to a maximum of 12.0 G's. In the WATT-SEC position with the range switch (on the main unit) set at the X1 position, the meter reads in watt-seconds and tenths of watt-seconds to a maximum of 120.0 watt-seconds. With the range switch in the X10 position, the meter reads in units of ten watt-seconds to a maximum of 1200 watt-seconds. For example, a reading of 107.5 represents 1075 watt-seconds. The meter may indicate readings higher than the above maximum values, but those values are close to meter saturation and should not be trusted. It would be better to suitably modify the run and retake the data. Once the data has been noted or recorded, the operator may reset the instrument by depressing the RESET button to clear the meter.

The average absorbed power in watts is calculated by dividing the accumulated energy in watt-seconds (determined from the meter reading and the range switch) by the run time in seconds.

ADDITIONAL FUNCTIONS

The ACC OUT (accelerometer output) banana jack pair provides a zero based, bipolar, analog voltage output scaled at 1.0 G per volt, with an upward acceleration represented by a positive voltage on the red jack with respect to the grounded black jack. This signal can be recorded during a run and played back for analysis at a later time. If the connection between the ACC OUT and TAPE IN is maintained, this signal can be recorded during a normal measurement run. The output limits are ± 12 G's or volts. The load impedance should not be less than 5000 ohms.

The TAPE IN (analog acceleration signal) banana jack pair provides a method to determine the instantaneous and average absorbed power for any segment of pre-recorded acceleration data. The recording medium is assumed to be tape, but any medium including digital can be used so long as the resulting signal is converted to analog form, has the proper scale factor, and contains the original frequency information from 0.1 to 50 Hertz. The scale factor, polarity, and limits are the same as those of the ACC OUT.

In order to use this input, the shorting jumper between ACC OUT and TAPE IN must be removed. A properly scaled analog acceleration signal from a data recorder must be connected to TAPE IN terminals, ground to black and signal output to red. NOTE: All black banana jacks are tied together and connected to the instrument case ground, which is normally connected to vehicle ground. Operation in this mode proceeds the same as an actual run: Make sure the timer is not running; RESET the meter; Start the playback machine; Press the START-STOP button to start the measurement when desired; Press the START-STOP button again to stop the run; Note and record the three readings and the range switch setting; Stop the playback device; Calculate the average absorbed power.

The FIL ACC OUT (filtered acceleration output) banana jack pair is provided for use with a visual recording device such as a strip chart recorder or oscilloscope. The FIL ACC OUT signal is the accelerometer signal re-scaled to feet per second squared and filtered to remove frequencies above 360 Hertz. The scale factor is 10 feet-per-second-squared/volt and the output limits are ± 120 feet-per-sec-squared or ± 12 volts. The load impedance on this output should not be less than 5000 ohms.

The ABRB PWR OUT (absorbed power output) banana jack pair is also provided for use with a visual recording device. This signal is a measure of the instantaneous absorbed power before the mathematical averaging process. The scale factor of this signal is 0.1 watt/volt with the range switch in the X1 position and 1.0 watt/volt with the range switch in the X10 position. In either case, the output limit is 12 volts. The load impedance on this output should not be less than 5000 ohms.

CALIBRATION

There are a total of eight calibration adjustments in this instrument. They are all accessible from the front panel. These adjustments can be divided into two categories; routine calibration and component replacement calibration. Routine calibration should be performed on the following: ACCEL OFFSET and GAIN, SQR OFFSET, WATT-SEC OFFSET, TIME OFFSET, and TIME CAL. ACCEL OFFSET and GAIN should be checked each time the instrument is used and with any change of accelerometer used with the instrument. The remaining four calibrations in the routine group need be checked only every six months unless a large change in operational temperature, say 30° F, or more, or severe shock to or vibration of the instrument has been encountered Component replacement calibration includes routine calibration plus the adjustment of X1 CAL and WATT-SEC CAL. These repairs and adjustments should be made only by a trained technician. This calibration is necessary only after internal components have been replaced due to component failure or when response to routine calibration is improper.

Routine Calibration Procedure

There will exist considerable variation in scale factors and offsets among the accelerometers used with this instrument. This instrument can be adjusted to compensate for these accelerometer variations. It is therefore necessary to associate a particular accelerometer with each instrument, and include that accelerometer in the routine calibration procedure.

- The unit should be connected to a 26 ± 4 Volt DC power supply with at least a 250 milliampere capacity.

- All cables should be properly connected, including the accelerometer and its cable.
- The ACC OUT - TAPE IN jumper should be in place.

Accel Gain & Accel Offset:

- Connect a DC multi-voltmeter with 0.5% or better accuracy across the FIL ACC OUT terminals.
- Place the accelerometer on a firm surface to sense vertical acceleration in the same direction as installed in a vehicle.
- Adjust ACCEL OFFSET until the voltmeter reads within 15 millivolts of zero.
- Place the accelerometer so that its sense axis is perpendicular to its zero position. (Lay it on its side.)
- Adjust ACCEL GAIN until the voltmeter reads within 50 millivolts of -3.22 volts. If the voltage is positive, the sense axis of the accelerometer is reversed. (Rewire by flipping the output leads on the accelerometer connector.)

  A certain amount of interaction between the above adjustments can be expected. Continue by alternating between the two adjustment procedures until both conditions are met.
- Disconnect the multi-voltmeter from the unit.

Sqr Offset:

- Connect a DC multi-voltmeter with 0.5% or better accuracy across the ABRB PWR OUT terminals.
- Remove the jumper between ACC OUT and TAPE IN terminals.
- Short circuit the TAPE IN terminals with the jumper.

- Adjust SQR OFFSET until the voltmeter reads within 3 millivolts of zero.
- Disconnect the multi-voltmeter from the unit.

Watt-sec Offset:

- Short circuit the TAPE IN terminals.
- Place the instrument panel meter switch in the TIME position.
- Press the RESET button to reset the timer.
- If necessary, operate the START-STOP button to stop the timer.
- Move the panel meter switch to the WATT-SEC position.
- Adjust the WATT-SEC OFFSET to reduce the drift of the least significant digit of the panel meter to less than once in ten seconds.

  It is not necessary for the meter to be reading zero for this adjustment. As a final check, RESET the panel meter, and note the time it takes to register a least significant digit change. If it is less than 10 seconds, perform a readjustment.

Time Offset & Time Cal:

- Place the instrument panel meter switch in the TIME position.
- Press the RESET button to reset the timer.
- If necessary, operate the START-STOP button to stop the timer.
- Adjust the TIME OFFSET to reduce the drift of the least significant digit of the panel meter to less than once in ten seconds.

  It is not necessary for the timer to be reading zero for this adjustment. As a final check, RESET the panel meter, and note the time it takes to register a least significant digit change. If it is less than 10 seconds, perform a readjustment of the TIME OFFSET.

- When the offset adjustment is satisfactory, RESET the timer.
- Using a stopwatch or clock with a sweep second hand as a reference standard, operate the timer for 60 seconds using the START-STOP switch.

  If the timer reading differs from 60.0 seconds by more than 0.3 seconds, make a one turn adjustment of TIME CAL.

  RESET and rerun the timer again for 60 seconds.

  Note the time difference that one turn made, and make a proportional corrective adjustment of TIME CAL.

  Continue the above procedure until the timer reads 60.0 ± 0.3 seconds.

This concludes the routine calibration procedure.

COMPONENT REPLACEMENT CALIBRATION

After a component is replaced, the routine calibration procedure must be completed first before performing this calibration procedure.

X1 Calibration:

- Connect an oscillator operating at 10 ± 1 Hz sine wave into the TAPE IN terminals.
- Set unit range switch to X10.
- Connect a heavily damped multi-voltmeter across ABRB PWR OUT banana jacks.
- Adjust the oscillator sinewave amplitude for a reading of 0.5 ± .05 VDC on the 10 volt scale of the multi-voltmeter, and note the multi-voltmeter reading.
- Set unit range switch to X1.
- Adjust X1 CAL so that the new meter reading is just ten times the noted previous reading.

WATT-SEC Calibration:

- Connect an oscillator operating at 10 ± 1 Hz sine wave into the TAPE IN terminals.
- Set unit range switch to X10.
- Connect a heavily damped multi-voltmeter across ABRB PWR OUT banana jacks.
- Adjust the oscillator sinewave amplitude for a reading of 0.5 ± .05 VDC on the 10 volt scale of the multi-voltmeter, and note the multi-voltmeter reading.
- Place the instrument panel meter switch in the TIME position.

- Press the RESET button to reset the timer.
- If necessary, operate the START-STOP button to stop the timer and RESET it to zero.
- Operate the timer for 100.0 seconds using the START-STOP switch.
- Move the panel meter switch to the WATT-SEC position.
- The WATT-SEC reading on the panel meter should be 100 times the reading in the multi-voltmeter. For example, if the multi-voltmeter reads 0.524, the WATT-SEC panel meter should read 52.4 ± 0.5 units.
- If the panel meter reading differs from 100 times the multi-voltmeter reading, make a one turn adjustment of WATT-SEC CAL.
- RESET and rerun the timer again for 100 seconds.
- Note the time difference that one turn made, and make a proportional corrective adjustment of WATT-SEC CAL.
- Continue the above procedure until the watt-sec panel meter reads 100 ± 1 times the reading on the multi-volmeter.

This concludes the total instrument calibration procedure.

EQUIPMENT LIST - ABSORBED POWER METER

1 Main processor unit with carrying case

1 Remote meter panel

1 Start-Stop pendant switch with cable

1 Interconnect cable - main processor to remote meter panel

1 Power input cable - main processor to 24 v.d.c. source

1 Accelerometer input cable - connector only

1 Banana plug jumper cable

SUGGESTED ACCOMPANYING ACCELEROMETER:

Model JTF Order Code AG 112 Accelerometer

Range ± 10 g

Sensitivity 10 mv/g

Sensotec, Inc.

1200 Chesapeake Ave.

Columbus, OH 43212